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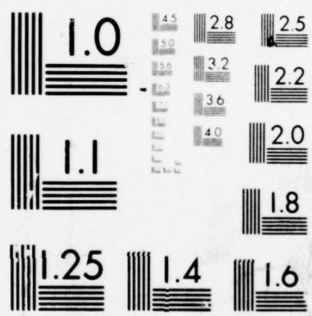

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A DYNAMIC POLICY MODEL OF THE UNITED STATES ARMS TRANSFER PROCESS.

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The transfer of arms between countries plays a significant role in the political, economic, and military affairs of the entire world, and is, consequently, subject to constant criticism and review from many quarters. Because of the complexity of the relationships in, and the diversity of opinion about arms transfers, a concise policy which will satisfy everyone is virtually impossible to devise. This thesis is an attempt to bring together all of the significant variables concerning the arms transfer system, with particular emphasis on the welfare of United States' national interests. While this model will not be able to produce policies which will keep all interested parties satisfied, it should depict the consequences of arms transfer decisions in terms of the major variables. The model will also facilitate the examination of policies such as the dollar ceiling on sales in terms of impact on the strategic position and economy of the United States.

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A DYNAMIC POLICY MODEL OF THE UNITED STATES ARMS TRANSFER PROCESS

A Thesis

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

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In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Logistics Management

By

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September 1979

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has been accepted by the undersigned on behalf of the faculty of the School of Systems and Logistics in partial fulfillment of the requirements for the degree of

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CHAPTER I

INTRODUCTION

Overview

Arms transfers include all defense articles and services provided by the United States (U.S.) to foreign countries, foreign private firms, and international organizations. All arms transfers are subject to the Foreign Assistance Act of 1961, as amended, and the Arms Export Control Act of 1967, as amended (35:2), and must be in the national interests of the United States. Arms transfers can be classified as:

1. Grant Aid (GA), under which the U.S. Government (USG) gives defense articles and services to selected foreign countries with no reimbursement (35:8).

2. Military Export Sales (MES), which comprise:

   a. Foreign Military Sales (FMS), under which the USG sells defense articles and services to foreign customers (35:7).

   b. Commercial Sales, under which U.S. private firms sell defense articles and services directly to foreign customers without involving government-to-government agreements (35:3).

Since World War II, the control of arms transfers has been a major instrument of U.S. foreign policy. By either approving transfers of arms or withholding arms, the United States Government has to some extent influenced the balance of power in many regions of the world. From the early 1960s onward, the major portion of arms transfers has comprised FMS, all of which, with the exception of some special restraints in Latin America and Africa, the President and Congress have been inclined to approve (38:17). Since 1974, the volume of sales has mushroomed into a multibillion dollar export industry for the U.S. Although only a small portion (about 4 percent) of overall U.S. exports, deliveries under FMS (the most significant part of MES) amounted to approximately $7 billion in FY 1977 (33:5-13; 35:4). Sales approved in the same period totaled about $11 billion (34:1).

In spite of the benefits which the arms transfer market has created for the U.S. defense industry, the volume of arms sales has reached a level sufficient to generate political concern.

> The virtually unrestrained spread of conventional weaponry threatens stability in every region of the world. Total arms sales in recent years have risen to over $20 billion, and the U.S. accounts for more than one-half of this amount . . . Because of the threat to world peace embodied in this spiralling arms traffic; and because of the special responsibilities we bear as the largest arms seller, I believe that the U.S. must take steps to restrain its arms transfers [3].

As a result of this political concern, ceilings on the dollar volume of FMS to non-allied countries were introduced in 1977 ( ).

Although the conduct of MES is controlled by several Acts of Congress and by various executive directives, and although it now involves many export dollars,

> There is presently no single, formally established means for policy control of all programs for the transfer of U.S.-origin defense articles and defense services. Transfers under Foreign Military Sales (FMS) procedures are controlled through an informal system of direct coordination between Defense and State and ACDA [Arms Control and Disarmament Agency], with State making the final decision on the proposed sale [38:44].

Implementation procedures for FMS have grown out of the management structure for Grant Aid, and consequently responsibility is divided mainly between the three military departments.

A report issued by the Senate Committee on Foreign Relations in 1977 identified a number of problems which existed within the arms transfer system:[1]

> --its essentially ad hoc and fragmented character;
> --the multiplicity of decision channels;
> --the lack of a single document or coherent series of documents on policies, planning, and procedures;

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[1]For the purpose of this study, the arms transfer system encompasses sets of national interests and their relations (commonly known as foreign relations), national military establishments, and national economies and international trade. The interaction between all of these produces, inter alia, the flow of arms between nations, with the focus here being primarily on the flow of arms between the U.S. and other countries. These arms flows influence, in turn, national military establishments, foreign relations, and national economies.

--difficulty in controlling all significant decision points; and

--inadequate interagency planning [38:45].

The General Accounting Office maintained in a 1979 report that all of the problems extant in 1977 still exist, even though the Carter Administration has issued broad policy guidance and formed an advisory Arms Export Control Board (30:i-vii). These problems prevent the definition of precise and effective policy guidelines for arms transfers and hinder the ability of responsible agencies to provide the necessary analysis for high level (including Presidential) policy review (38:46).

Because the arms transfer process plays a significant role in the political, economic, and military affairs of the entire world, it is subject to constant criticism and review at all levels of government.

Problem Analysis

Criticisms of the arms transfer system have been raised in numerous studies and reports by members of both the government and the military. "The diversity of opinion about arms transfers makes it impossible to devise a concise statement of the problem that will satisfy everyone [38:41]." Those people critical of arms transfers have cited problems such as:

--lack of appropriate Congressional control;

--creation of regional arms races;

--creation of a "merchants of death" image for the U.S.; and

--depletion of U.S. forces' inventories to meet sales needs.

On the other hand, those in favor of MES have argued:

--strong allies and friends will reduce the likelihood of U.S. involvement in foreign conflicts;
--lower cost of certain U.S. weapons, minimizing cost of defense to taxpayers;
--keeps weapons production lines open when weapons are not being produced for U.S. military; and
--it [FMS] [is] a source of influence with customer countries [5:63].

With this number of opposing effects of arms transfers, it is clear that the interpretation of arms transfer policy can depend on individual or agency viewpoint. This is symptomatic of a lack of a systems approach; in other words, each individual or agency perceives only a portion of the total arms transfer system and is prone to describe the policy control problem in correspondingly narrow terms. Given this situation, the following problem statement was formulated.

Problem Statement

The impact of arms transfer policies upon U.S. national security, foreign relations, and economic conditions is not completely understood by strategic level[2] security policy managers.

---

[2]The function of management relevant to this study is strategic level planning, which Anthony defines as follows:

"Strategic [level] planning is the process of deciding on objectives of the organization, on changes in these objectives, on the resources used to attain these objectives, and on the policies that are to

Justification for Research

There have been a number of other studies which have recognized the need for a clearer understanding of how the arms transfer system influences national security, foreign relations, and the economy. Perhaps the most significant of these is the 1977 Senate report referenced above. This report suggested the establishment of a centralized FMS planning and analysis system to review overall FMS policy and impact. This system would continually assess the threats to customer nations, review past and proposed purchases, and assess the implications of arms transfers on political, military, and economic issues in U.S. relations, all in light of the U.S. national interests (38:48). A systems analysis of the arms transfer system would be necessary for the development of such an assessment system.

In addition, McChesney (18:248) has stated that the Departments of Defense and State should clarify the role of FMS in the U.S. foreign policy structure. To be effective, such a clarification would require that policy-makers be able to assess the many effects of various

---

govern the acquisition, and the disposition of these resources . . . [15:16-18]."

For the purpose of this study, strategic level planning involves the design of decision making rules by the President, Congress, and the Department of State for the guidance of State and Defense managers, who are required to implement and control the arms transfer system in order to accomplish certain national security objectives.

policy options. This assessment, in turn, would be facilitated by a systems analysis of the arms transfer system. This study comprised such a systems analysis and was conducted in accordance with the following research objectives.

Research Objectives

Having introduced the nature of the problems in the arms transfer process, and having stated the basic problem itself briefly, it is now possible to outline the objectives of this research effort. Accomplishment of these objectives contributed to a solution to the problem stated above.

The general objective of this research was to enhance conceptual understanding of the arms transfer system and to determine that system's behavior in reaction to various changes in U.S. arms transfer policy. Specific objectives included:

1. To identify and describe the components of the arms transfer system;

2. To describe the relationships between these components, including the system's decision structure;

3. To construct a mathematical model which will represent the relationships between system components;

4. To translate the mathematical model into a dynamic system model suitable for computer procession;

5. To generate the behavior of the arms transfer computer model over time, given certain sets of arms transfer policies;

6. To validate the computer model by comparisions of predicted behavior with real world behavior; and

7. To use the computer model to suggest changes to U.S. arms transfer policies and policy-making structures which will further the realization of U.S. national interests and objectives.

The question remained as to whether this research could be successfully accomplished. Thus, it was necessary to pose a research question, which was answered as the research objectives were completed.

Research Question

To what extent can a dynamic policy model be developed which will capture the behavior of the arms transfer system and serve as a means to investigate the relationships between arms transfer policy, national security, foreign relations, and economic conditions?

Summary and Preview

This chapter has briefly examined the nature of the problems of policy control in arms transfers. A basic problem was identified, along with a list of objectives that were accomplished toward problem solution. Finally, the fundamental question which was answered by this

research was posed. In Chapter II, the research effort focuses on related information; Chapter III presents the research methodology; Chapter IV details the construction of the conceptual arms transfer system model; Chapter V presents the development of the computer model from the conceptual model; and Chapter VI contains conclusions, recommendations, and suggestions for further research.

CHAPTER II

THE ARMS TRANSFER SYSTEM AND POLICY MODELING

Introduction

Information associated with this research project has been classified into two main areas of interest; one of these examined the current strategic level planning for arms transfers in terms of the foreign relations, national security, and U.S. economy subsystems, while the second area concentrated on techniques available to model the relationships. This chapter is devoted to reviewing two areas of interest and illustrating how each contributes to the construction of a dynamic model of the arms transfer system.

Foreign Relations

The relationship between arms transfers and U.S. foreign policy is couched in the Arms Export Control Act (AECA) (27). "It is the sense of Congress that arms sales shall be approved only when they are consistent with U.S. foreign policy interests [27:Sec 1]." The major problem that is encountered in attempting to describe the relationship is that foreign policy, while relatively easy to

define academically,[3] is always changing as situations in the world change, often dramatically (e.g., U.S. recognition of the Peoples Republic of China and the revolution in Iran).

Although there do not appear to have been any dynamic models which describe foreign policy and its effects on arms transfers, a static systems approach has been considered for foreign policy. Esterline and Black (6:3,4) conclude that in view of the large number of variables, such "analysis of foreign policy of the U.S. will be incomplete at best."

In the current study, a modeling of the entire foreign policy system, incorporating thousands of variables, was not attempted. Instead, foreign policy variables were developed from the sales approval tests Congress has established in the AECA and from a series of questions raised in a statement by then-Secretary of State Kissinger:

> 1. What is the nature and intent of the threat to the security of the recipient nation? Do we agree on the nature of the threat? Involved here is the role that the country plays in its region and in the world, its capacity to maintain its stability, and its will to defend its own interests.
> 2. What is the U.S. interest in helping to preserve that security? What interest does the recipient

---

[3] "It [foreign policy] is . . . official governmental acts and relationships involving other nations and international organizations [6:2]."

have in common with us and where do our interests diverge? What potential influence for restraint or positive conduct is involved?

3. What other nations are involved in military transfer to the recipient--now or potentially? What options has the recipient? Will refusal lead it to turn to another source of supply, perhaps altering a presently desirable international relationship?

4. And what are the consequences for us if we fail to respond? What are the disadvantages of refusing to sell to a government with which we enjoy good relations? Will regional or even global military balance be affected? What will be the impact on our own readiness [16]?

The numerous limitations and restrictions enunciated in the AECA will not be listed here. Suffice to say that they have been imposed in an effort to guarantee the correct arms transfer decisions in light of the questions raised above.

National Security

The influences that arms transfers and U.S. national security exert on each other are more subtle than are those between arms transfer and foreign relations. This situation arises because the U.S. government agency responsible for national security, the Department of Defense (DOD), is not only affected by the quantity of arms held by other countries, but its readiness can be affected by the quantity of FMS it must manage. The former problem, concerning the level and distribution of military hardware and skills in the rest of the world, has already been

addressed under foreign relations. The impact of managing FMS on U.S. readiness will be addressed here.

> While increasing the likelihood, or at least, increasing the ability of a country to participate in a war, FMS may also decrease the ability of the U.S. to fight those wars if necessary [19:41].

Parker and Hawxhurst have examined the impact of FMS on U.S. readiness under the three areas of material readiness, logistics support, and supply support. Particular situations which can adversely affect U.S. readiness are the manpower drain for FMS management and the lower levels of depot stocks as a result of commitments to support other countries at war.

Furthermore, within a Cooperative Logistics Supply Support Arrangement (CLSSA), when items are in short supply, a foreign customer with a higher Force Activity Designator (FAD) than a U.S. military unit will have its demand satisfied first. Although the Joint Chiefs of Staff (JCS) assign FADs according to Total Force considerations, U.S. readiness can be prejudiced in some instances (19:41-45).

U.S. national security is, therefore, not only affected by the international implications of FMS, but can also be influenced by problems associated with the management of FMS. These internal effects can also be extended to Commercial Sales in an indirect sense, in that U.S.

industry is also committed to use resources and allocate priorities, sometimes at the expense of DOD.

U.S. Economy

> One of the elements of current debate on U.S. policies regarding the sales of arms abroad has been the economic consequences of significant changes in the FMS program. Assessment of these consequences centers on two issues: the budgetary cost savings to the U.S. which result from FMS and the macroeconomic effects of such sales [28:ix].

A study of the macroeconomic effects of restraint in arms transfers was accomplished by the Department of the Treasury in 1977. The study was conducted on several different types of economic simulation models. "Macroeconomic simulations were performed by the Office of Policy Research at the Treasury using the DRI Trendlong economic model of the U.S. economy [38:75]." Computation of effects of alternative policies towards arms transfers on particular industries were performed by the Office of Economic Growth at the Bureau of Labor Statistics (38:76), while regional employment effects were computed by the Office of Economic Research at the Commerce Department using the IDIOM-II model (38:77).

In addition to these macroeconomic models, the Congressional Budget Office has prepared a study which quantifies the budgetary cost savings attributed to FMS.

A detailed review of these simulation studies will not be conducted here because their reports are lengthy

and without exception, based on differing assumptions and conditions. What is apparent, however, is that there are numerous models available to investigate the interrelationships between the U.S. economy and arms transfers. The current research used some of the technology from several of these in the development of a dynamic model of the arms transfer system.

The above considerations of various aspects of U.S. foreign policy, national security, and the economy provide an overture to a systems analysis of the entire arms transfer system. This systems analysis is part of the process of modeling.

Overview of Policy Modeling

Modeling is the act of developing simplified representations of reality (models). Models may be classified as iconic (scale models), analog (models which reproduce behavior but not appearance), or mathematical (models which abstract reality into symbology); they may also be classified as prescriptive or descriptive. Models may be used to represent systems, or interconnected groups of things. In this connection, it is necessary to define system variables, system environment, and system boundary.

--System or endogenous variables are those variables whose values change as the system operates;

--The environment includes those (exogenous) variables whose values are not affected by system operation;

--The system boundary is the dividing line between the system and its environment, and reflects the area of concern of the modeler [13:22,23; 26:16-20,24].

A policy model, then, is a simplification of a system (the simuland), which attempts to describe system behavior under varying policies (8:102). Such a policy model may fall into one of three categories, depending on whether the simuland:

1. Can be described by a mathematical model which can be solved analytically (an analytical model has a single optimal solution or best state of affairs);

2. Can be described by a mathematical model which cannot be solved analytically; or

3. Cannot be described by a mathematical model.

Typically, the first category includes only very simple models, due to limitations in analytical techniques. The second category includes many complex systems, including some social systems, while the third category contains systems so complex that modeling and simulation are not presently possible. Thus, modeling and simulation would appear to be the only available techniques for analysis of many systems (21:5).

In fact, Beer (2:98,99) has stated that modeling and simulation may be the techniques of first choice when embarking on an analysis of a system. A system can be composed of literally billions of variables, and there is no rigorous way of knowing which variables have noticeable

impact on system behavior. Part of the modeler's task is to simplify these billions of variables into some manageable number of significant variables as best he can. This is apparently the only way to begin the investigation of any even moderately complex system. Additionally, Beer questioned the limited methodology of attempting to optimize one variable at a time in a system. He noted that variable systems attempt (unsuccessfully) to optimize all variables at once, thereby achieving a balance. The direct analogy for social systems is that optimization is impossible, and that possible system behaviors can be compared based only on the preferences of managers.

Thus, modeling and simulation have emerged as the premier techniques for dealing with complex systems. The use of modeling, however, is based on certain premises.

Premises of Modeling

Forrester (8:13,14) has stated four premises of modeling:

> --Management decisions are made in general frameworks known as information feedback systems[4];
> --Intuitive judgments of a system behavior are unreliable, even when parts of the system are well understood by managers;
> --Improvements in system performance are possible; and

---

[4]An information feedback system is characterized as a system whose current state influences a decision which results in an action which brings about a change in the system, which in turn influences a future decision (8:14).

--The mechanistic model structure provided by systems analysis is true enough to reality to permit meaningful analysis.

These premises address the nature of a system, the possibility of modeling it, and the utility of doing so. The second and third premises are directly in line with the justification of modeling above, while premises one and four look forward to the sections below.

Advantages, Limitations and Disadvantages

The advantages of modeling over direct experimentation with the system of interest are real and many. Perhaps the most important advantage of modeling social systems is the possibility of experimentation. Variables in the model may be changed as desired and the simulation run any number of times. In real social systems, however, experimentation is frowned upon, if not impossible, and it is generally impossible to duplicate a given system's environmental conditions later on. Along the same line, it is possible in the model to note the effect on changing only one variable, which again is generally impossible in the system. Control of time is another important advantage; processes taking years may be simulated in seconds using digital computers. Simulation is also safer, in that any unpleasant effects of policy changes are felt only in the model, not in the system. Also, it is possible using a model to analyze systems which do not exist,

but are only hypothetical or proposed. Finally, it is generally cheaper to experiment with models than with systems (8:5; 12:359).

Despite these sizeable advantages, several limitations on and disadvantages of modeling exist. Complex models suitable only for computer processing are constrained by the capacity of digital computers and the cost of operating them. Models cannot predict the future, although some researchers have relied upon them to do so. They cannot be validated except in relation to their assumptions (12:368; 13:13; 21:5). Besides these limitations, there are two major disadvantages.

One disadvantage lies in the tendency of the modeler to include too much detail in the model. This effort consumes resources, often without any increase in utility. However, the major disadvantage is the attempt to model systems inappropriately. Inappropriate systems include those which can be dealt with more effectively by analytical techniques and those which cannot yet be conceptualized logically (12:368). In summary, comprehension of the limitations and disadvantages of modeling is essential for assessing the validity and utility of a model (13:13).

Techniques, Use, and Implementation

Systems analysis is usually the first step in modeling. Systems analysis consists of identifying system components, relationships, boundary, environment, and possible states. The next step is the development of influence diagrams, which can be used to express relationships in information feedback systems. Such diagrams greatly simplify illustration of systems in that they are preliminary graphical models. The third step in modeling is to construct a flow diagram. Whereas the influence diagram expresses only the general nature of relationships, the flow diagram expresses relationships mathematically and often enhances the logic of the influence diagram (10:5).

After development of the flow diagram, it is necessary to operationalize the model (write computer code suitable for processing), to verify the operationalized model, and to validate it. Verification consists of ensuring that the computer code performs properly, while validation consists of ensuring that the mechanized model adequately simulates system behavior (13:23).

Once the model is performing adequately, it can be used to exhibit system behavior under differing policy options. Fromm (13:129) has suggested that the primary benefit of using models lies in the education of managers

at all levels as to the general nature and behavior of their systems, and not specifically in the policymaking assistance. Forrester (8:128), in agreement with Fromm, has stated that the principal use of a model should be to increase understanding of the system, and not to predict the future. In any event, better understanding should enable strategic level managers to make better policies (8:45). Additionally, since the purpose of modeling and simulation is to aid in the design of improved systems, it is necessary to implement policy recommendations suggested by the model (8:115). Implementation has been addressed adquately elsewhere [for example, see Turban and Meredith (26:489-507)].

Applications to Arms Transfers

In the first half of this chapter, the characteristics of the arms transfer system were examined, and sources for more detailed information were referenced. It remains to determine if the arms transfer system is appropriate for modeling and simulation.

The arms transfer system, taking into account political, military, and economic effects, appears to be operationally definable; that is, the variables in the system appear measurable. Consequently, the system should be susceptible to mathematical modeling, although its complexity could preclude analytical optimization. Models

of this nature are particularly amenable to aggregative simulation techniques.

Some simulations which can be linked to arms transfers have already been accomplished; their techniques and results will be employed as needed. Examples in the economic area include the Wharton (31) and DRI (38) macroeconomic models, and in the politico-military area the manual (uncomputerized) international relations simulation of Geutzkow (11) and the conflict models of Ferris (7).

Chapter I of this thesis addressed the nature of the arms transfer system, the need for a deeper understanding of the effects of arms transfers, and the research objectives. Chapter II summarized the information derived from a literature review and related to the arms transfer system. It also established that the arms transfer system is unsuited to analytical optimization because of its complexity, but that it should qualify for investigation through simulation using system dynamics. The next state in this effort was to conduct a systems analysis and develop an influence diagram of the arms transfer system using available information. Foreign policy and national economic effects were only considered to the extent that they interact with the flow of arms and military services from the United States. National interests, being inherently stable (4:1), were considered constant for the purposes of this research effort.

CHAPTER III

METHODOLOGY

Introduction

This chapter outlines the development of a dynamic model of the arms transfer system. It includes the creation of an Initial System Sector Diagram and its expansion; explanation of influence diagramming; a brief look at operational definition of variables; and explanation of flow diagrams. This chapter concludes with an outline of the method used for obtaining relational data and internal validation; equation writing; and a treatment of external validation and model analysis.

Initial System Sector Diagram

The first step in constructing a model of the arms transfer system was to bound the system in terms of the research problem and objectives. Because the impact of arms transfer policy upon U.S. national security, foreign relations, and economic conditions was the issue at hand, sectors representing these areas were included (see Figure 1).

The inherent behavior of this system, as depicted in Figure 1, is that as the U.S. political machinery makes

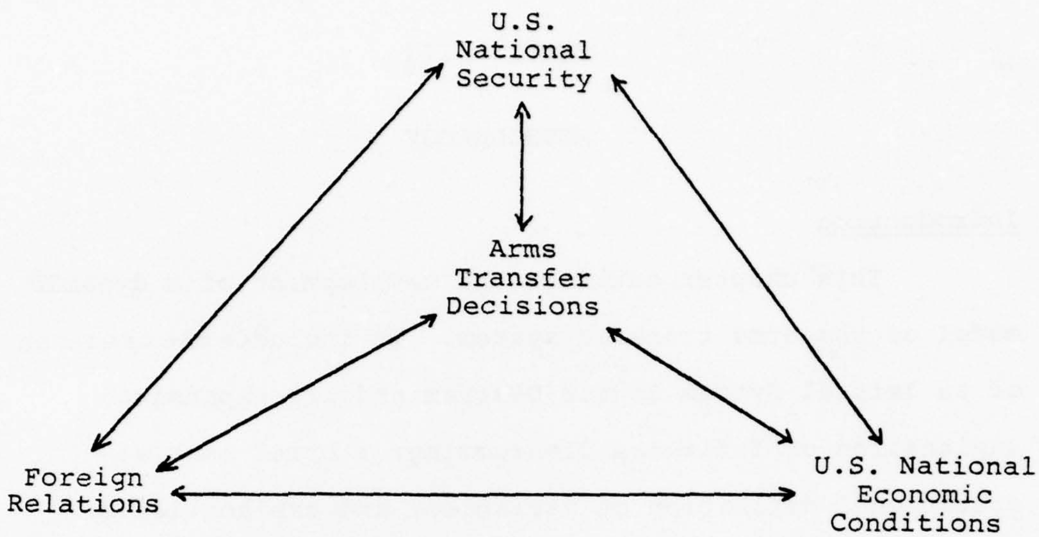

Fig. 1. Initial System Sector Diagram

decisions about arms transfers, national security, foreign relations, and the U.S. national economy are all affected. These effects can, in turn, influence each of the other sectors, including the U.S. political machinery's inclination to approve arms transfers.

Expanded System Sector Diagram

From the Initial System Sector Diagram, the arms transfer system was broken into smaller sectors to form an Expanded System Sector Diagram (see Figure 2). This process facilitated closer study of specific relationships without the confounding influence of numerous variables which appeared later in the model construction process.

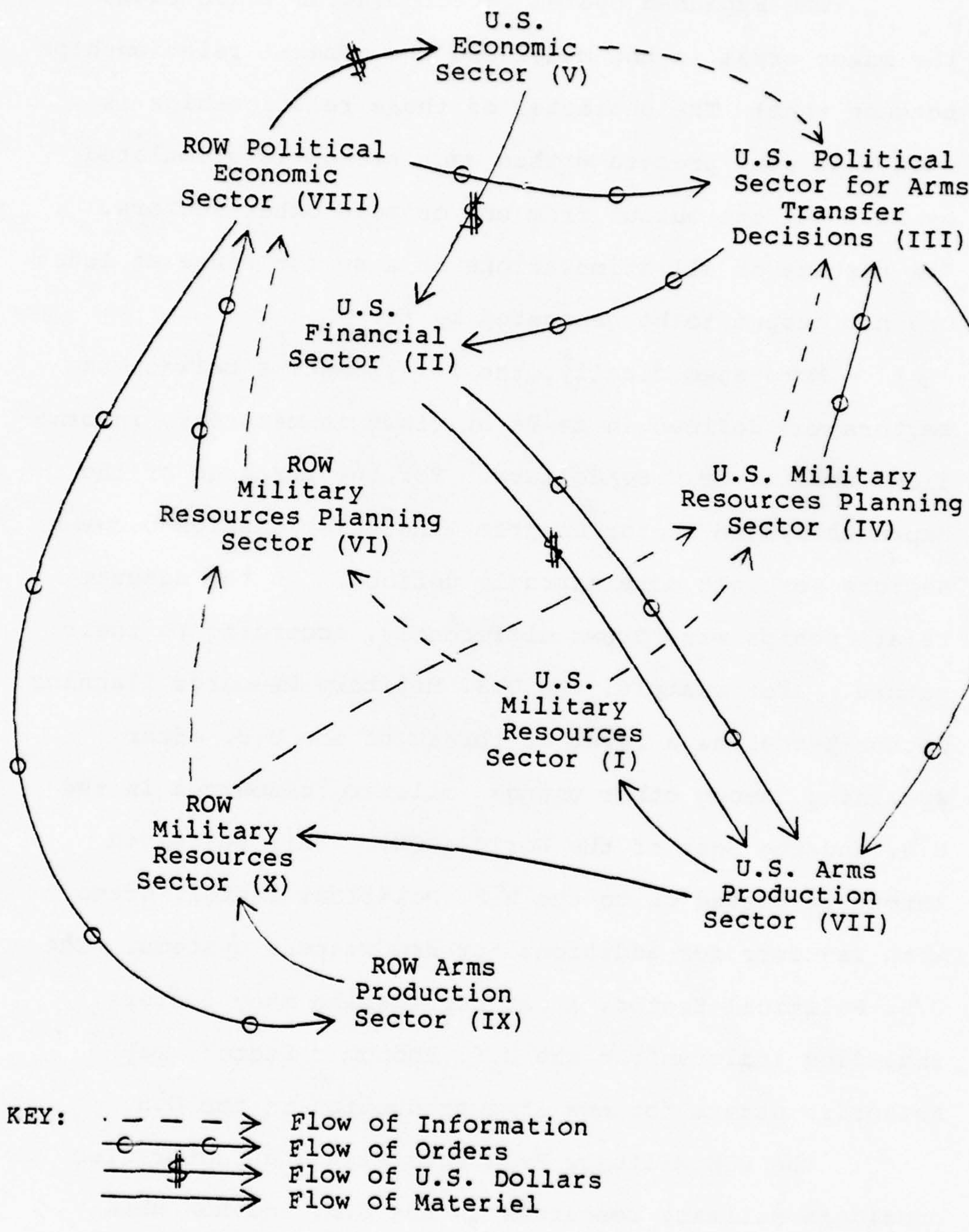

Fig. 2. Expanded System Sector Diagram

The Expanded System Sector Diagram illustrates the major areas in the model and the general relationships between them. The character of these relationships is such that some process within each sector is stimulated by at least one output from one or more other sectors. The results of all stimulations to a sector cause at least one new output to be generated by it.

More specifically, the relationships between the sectors were defined in terms of flows in material, information, orders, or U.S. dollars. For the purposes of the Expanded System Sector Diagram, the relationships between sectors were not more narrowly defined. In the diagram, relationships were drawn differently, according to their nature. For example, the U.S. Military Resource Planning Sector perceives a level of threat to the U.S. after examining, among other things, military resources in the U.S. and the Rest of the World (ROW). This perceived threat is passed on to the U.S. Political Sector, often with requests for additional or new weapons systems. The U.S. Political Sector, after considering many factors, including indices from the U.S. Economic Sector, may authorize orders for new arms production in the U.S.

The ROW Military Resources Planning Sector also considers military resources in the U.S. and ROW when determining threat levels and arms requirements. The

ROW Politico-Economic Sector can then authorize new arms production in ROW or send requests for arms to the U.S. If these requests are approved by the U.S. Political Sector, additional orders for arms production are passed to the U.S. Arms Production Sector through the U.S. Financial Sector. Arms produced will then flow to the U.S. and ROW military resource sectors respectively. Payments for arms produced in the U.S. for ROW are represented by a dollar flow between the ROW Politico-Economic Sector and the U.S. Economic Sector.

Although ROW is conceptually represented in the diagram as a single entity, all intepretations associated with ROW were arrayed in the fully developed model by country and by weapons' characteristics. The U.S. equivalent of the ROW Politico-Economic Sector has been broken out into the U.S. Economic Sector and the U.S. Political Sector to provide better visibility to the USG processes which are the primary concern of this study.

Influence Diagrams

Influence diagrams provide a breakout of the variables within model sectors and permit more detailed specification of how the variables affect each other. While these diagrams do not illustrate the nature of relationships in terms of material, information, orders, or U.S. dollars, they depict the existence of all relationships

between the variables and the direction of those influences. For example, in the U.S. Military Resources Sector (I), if U.S. Military Capabilities were divided between Continental U.S. (CONUS) Deployment of Military Capabilities and Overseas Deployment of Military Capabilities, assuming all other factors to be constant, as U.S. Military Capabilities increase, CONUS Deployment of U.S. Military Capabilities would also increase. This relationship is depicted in Figure 3, where the + indicates a direct relationship between the two variables.

U.S. Military Capabilities $\xrightarrow{+}$ CONUS Deployment of U.S. Military Capabilities

Fig. 3. Relationship Between U.S. Military Capabilities and CONUS Deployment of U.S. Military Capabilities Depicted in Influence Diagram Format

Similarly, albeit with some time delay, as CONUS Deployment of U.S. Military Capabilities increases, obsolescence or Retired Inventory increases (see Figure 4).

CONUS Deployment of U.S. Military Capabilities $\xrightarrow{+}$ Retired Inventory

Fig. 4. Relationship Between Retired Inventory and U.S. Military Capabilities Depicted in Influence Diagram Format

By the same token, as Retired Inventory increases, with everything else remaining unchanged, U.S. Military Capabilities will decrease (see Figure 5). Note that this is shown with a (-) sign since it is an inverse relationship.

Fig. 5. Relationship Between Retired Inventory and U.S. Military Capabilities Depicted in Influence Diagram Format

Finally, the diagrams shown in Figures 3, 4, and 5 can be combined to form a loop (see Figure 6). If the total number of (-) signs within the loop is odd (one in this case), the loop is negative and is so labeled in the center as shown. Negative loops are characterized by "goal-directed or goal-oriented behavior [10:37]." They contain some type of central mechanism which seeks to regulate the system. Positive loops, on the other hand, exhibit uncontrolled growth or decay.

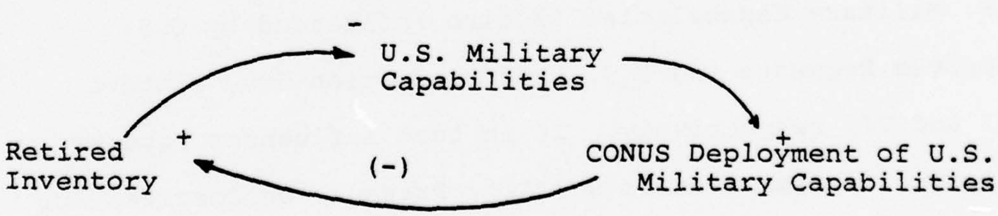

Fig. 6. Influence Diagrams Defining the Relationships Between U.S. Military Capabilities, CONUS Deployment of U.S. Military Capabilities, and Retired Inventory

By employing the same techniques, the U.S. Military Resources Sector of the Expanded System Sector Diagram has been developed into the influence diagram shown in Figure 7. Those variables which are members of other sectors are underlined.

U.S. Mlitary capabilities is the central variable in this sector. It is partially regulated by Retired Inventory through the Overseas Deployment of U.S. Military Capabilities as well as through CONUS deployment. Overseas deployments affect the cost of maintaining forces overseas in a positive manner, and they can be used by the USG to some extent to balance regional instability in the world (shown by a negative loop). A positive or re-inforcing loop is created between U.S. Military capabilities, Arms Transferred, Overseas Deployment of U.S. Military Capabilities and Retired Inventory because the U.S. will transfer arms to some countries so that they will be less dependent on the U.S. for military assistance in times of crisis (20:17). U.S. Military Capabilities is also influenced by U.S. Approved Requests and U.S. Arms Production from Sectors III and VII respectively. It in turn influences Popular Support for Arms Transfers (III), Pressure on Congress for Defense Dollars (II), Requested Arms for DOD (IV), Popular Support for Defense Spending (II) and ROW Perceived Threat from U.S. (VI).

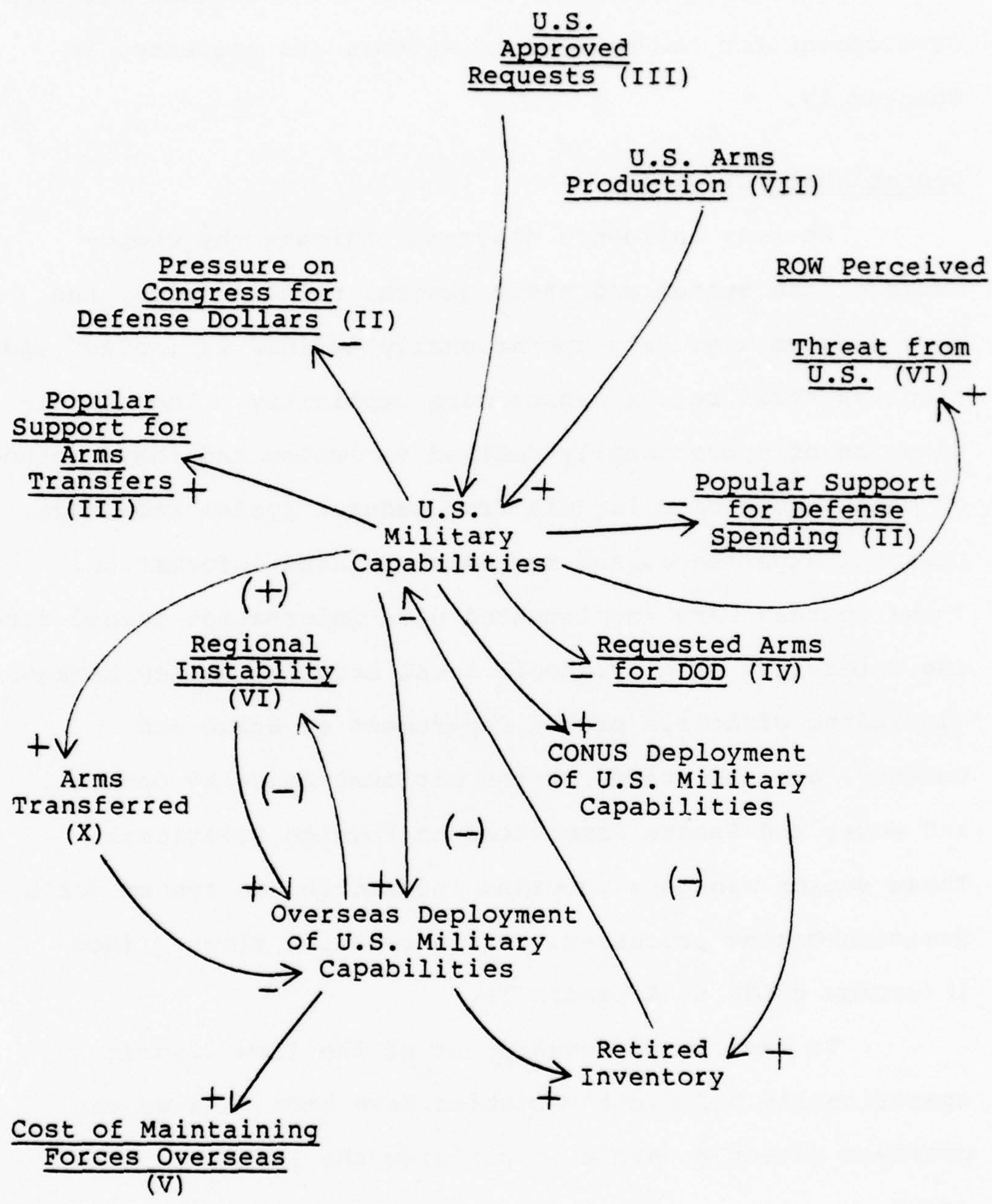

Fig. 7. U.S. Military Resources Sector (I)

Remaining concepticalization and influence diagram development for the other nine sectors are presented in Chapter IV.

Operational Definition

Whereas influence diagrams indicate the components of the system and their general relationships, the flow diagram uses only operationally defined variables[5] and displays their relationships more explicitly. The identification of operationally defined variables and their methods of measurement came largely from general system knowledge, personal experience, and review of related information. These sources were supplemented with information gained during interviews with strategic level security policy managers (including officials of the Department of State and Defense, and the staffs of the National Security Council, and House and Senate Committees on Foreign Relations). These senior managers provided information on system goals, decision-making processes, and information flows. (See interview guide at Appendix 1).

To facilitate development of the flow diagram, operationally definable variables have been used to the greatest extent possible in building the influence diagrams.

---

[5] An operationally defined variable is one whose definition specifies how that variable will be measured.

Flow Diagrams

A proposed flow diagram may be drawn once system variables are defined using the relationships of the influence diagram. A flow diagram is so called because it depicts directed continuous flows of materials, orders or requests, money, personnel or human capital, capital equipment, and information. A system can be modeled in terms of these six flows (see Figure 8) (8:70-71).

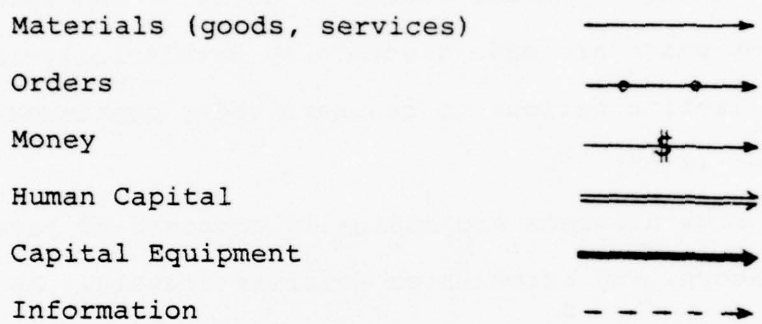

Fig. 8. Flow Symbols (8:82)

It may seem that using continuous flows in a model might not accurately simulate a system with discrete elements. For example, an order for goods is a discrete event, and the payment for delivered goods is a discrete amount of money tendered at a specific time. This problem can be resolved by noting that the focus in modeling is not on individual events, but on the behavior of the entire system over time. Therefore, what appear to be discrete events may be modeled by (time-varying) flows, simply by taking a broader view. An example of some importance can

be noted here. Decision-taking, which appears to be a discrete event for a given decision, can (and should) be viewed as a continuous process of consideration, implementation, and reconsideration (8:64).

There are other reasons for modeling systems in a continuous-flow manner. These include simplifying the model by aggregating unimportant detail into flows; countering the emphasis on analysis by placing the focus on synthesis; making the model easier to develop; and forcing variables which are made discrete by artificially-imposed data collection periods to reassert their continuous character (8:65).

Flow diagrams are basically composed of levels or accumulators, and rates which determine levels. As an example, consider a national arsenal. The inventory held is a level, which is determined by the inflow of new armaments at a certain rate and the outflow of obsolescent armaments at a certain rate. The inflow rate is influenced by perceived threat and availability of new armaments, while the outflow rate might be influenced by the level of armaments and a constant minimum rate of obsolescence (8:68-69).

A rate is determined by a rate equation, which is analogous to a policy. A policy is a rule for making decisions which control events; a rate equation accepts information as inputs and manipulates these inputs to produce a rate, which controls a flow. From the example

above, the outflow rate is determined by a rate equation which captures an obsolescence policy (8:69).

Using this method of depicting flows along with the symbology in Figure 9, flow diagrams such as Figure 10 were produced. Figure 10 is a flow diagram of the U.S. Military Resources Sector (8) of the arms transfer model. In this sector, a flow of arms from U.S. Completed Force Production (CFPUS) goes into the level U.S. Forces in the United States (USFC). From there, forces are retired through the delay USCFRR or deployed overseas to the level U.S. Forces Overseas (USFO). From USFO, forces may be redeployed to the U.S. or retired through USOFRR. Movement between USFC and USFO is controlled by the U.S. Force Overseas Deployment Rate (USFODR), which is detailed in Table 1.

After the complete flow diagram is developed, it is necessary to write the equations which describe the relationships between levels and rates. Before this can be done, however, these relationships must be determined.

Obtaining Relational Data and Internal Validation

The nature of the relationships between two operationally defined variables may be determined in one or more of several ways. As noted before, general knowledge, personal experience, and review of related information can bring to light the general nature or direction of a

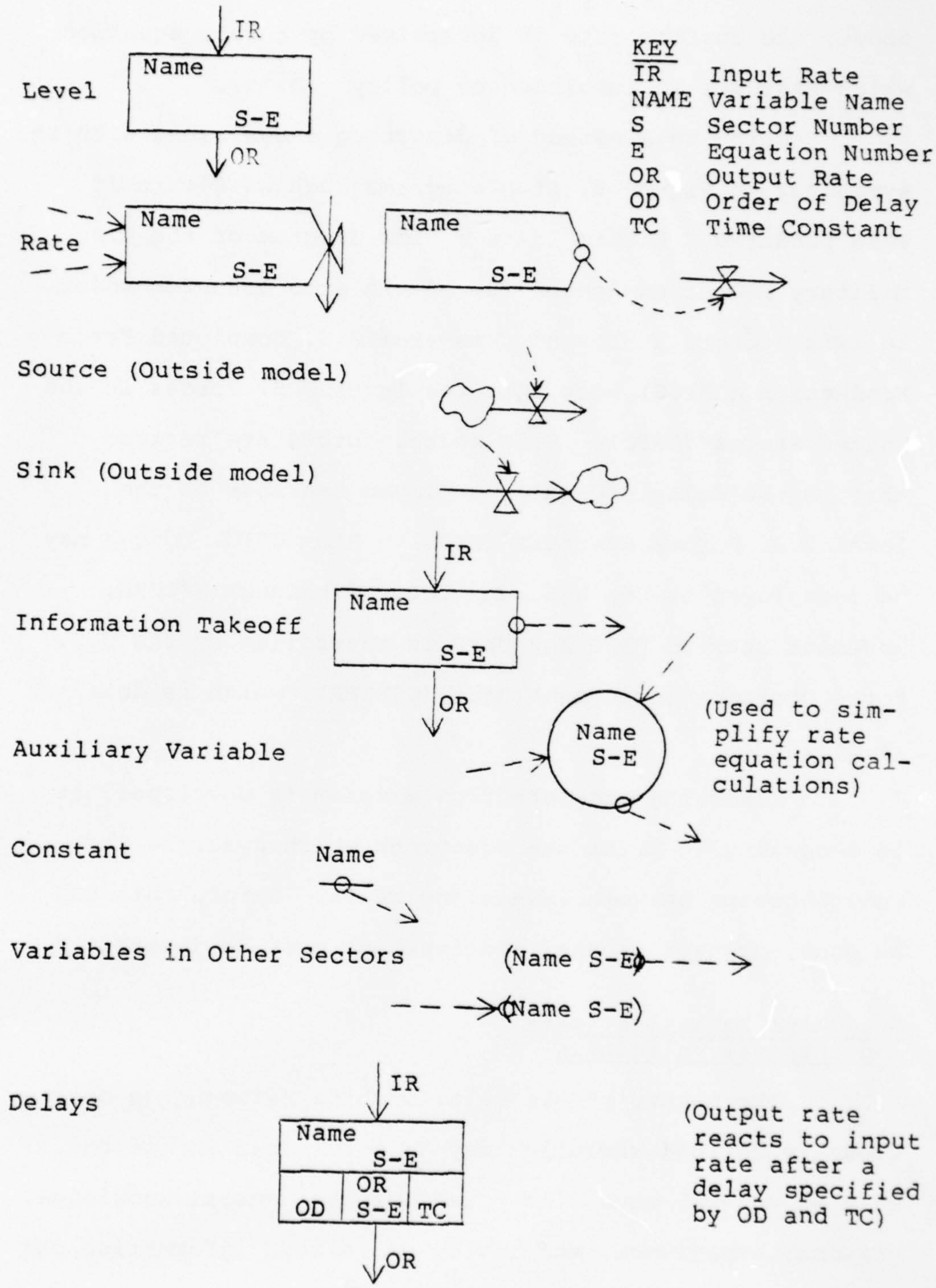

Fig. 9. Flow Diagram Symbology (8:81-84)

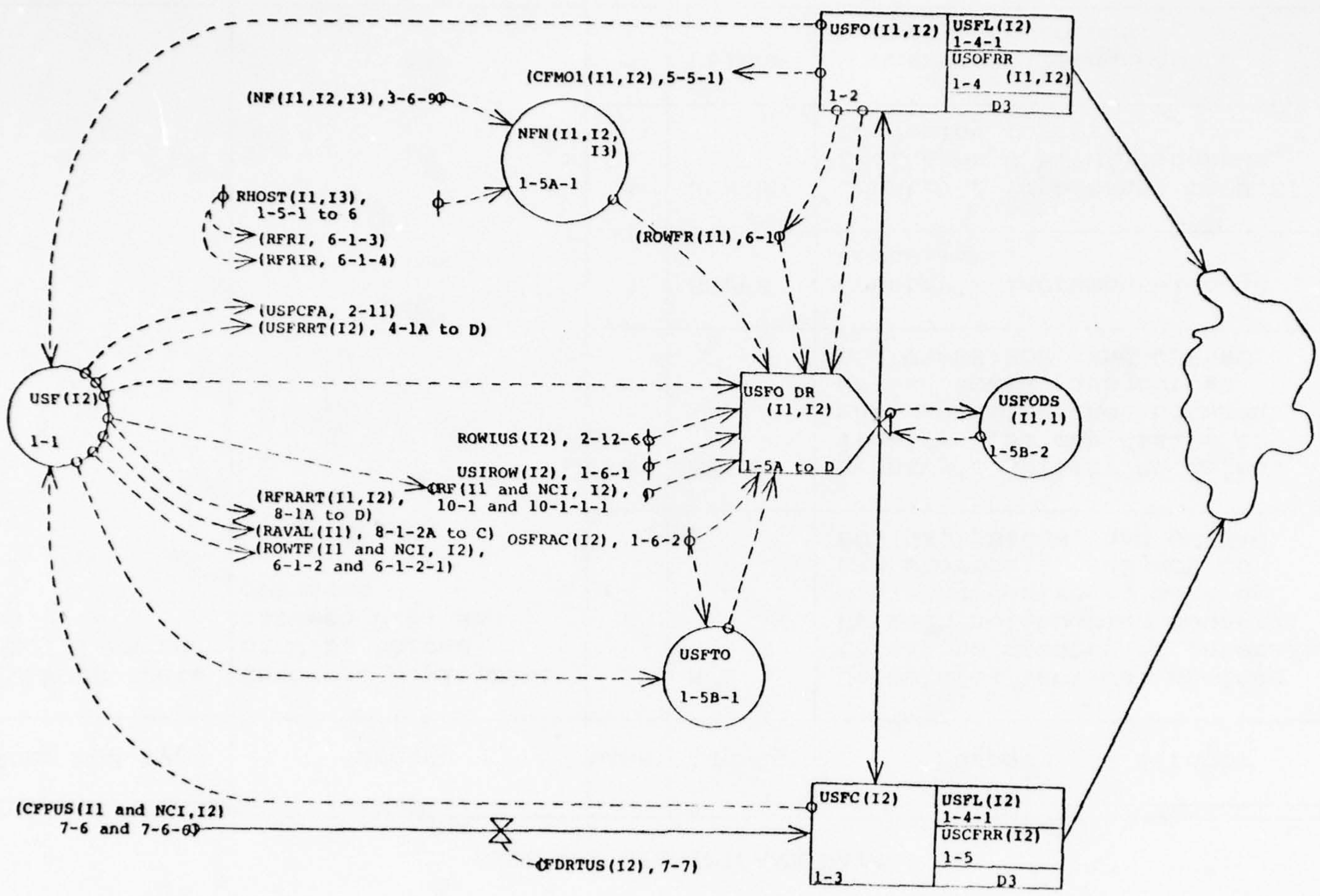

Fig. 10. Flow Diagram, Sector I

TABLE 1

SECTOR I SIGNIFICANT RATE

Name and Type	Purpose	Line	Inputs	Purpose and Effect
USFODR, rate Eq. 1-5A to D	Controls Deployment of U.S. forces between U.S. and overseas	1	NFN	Calculates tactical nuclear threat to country of interest by each neighboring country; U.S. may desire to make up any shortfall, subject to ROWIUS, USIROW, and OSFRAC.
		2	RF	Country's ability to defend itself; U.S. may desire to make up difference between RF and ROWFR, subject to ROWIUS, USIROW, and OSFRAC.
		3	ROWFR	Country's incremental need assessment.
		4	ROWIUS	Country's importance to U.S. Indicates U.S. willingness to deploy forces.
		5	USIROW	Country's willingness to accept U.S. forces.

TABLE 1--Continued

Name and Type	Purpose	Line	Inputs	Purpose and Effect
		6	USFTO	U.S. forces already deployed.
		7	USF	Total U.S. forces available.
		8	OSFRAC	Maximum fraction of USF deployable (U.S. policy)

NOTE: Deployment rates for modern and dated equipment are assumed to be zero.

relationship (i.e., equation), if it can be determined at all, may also be obtained from the information review or from statistical analysis of empircal data.

If only a general relationship between two variables could be determined, an approximation based on reasoned analysis was used to write the pertinent equation. This equation could then be subjected to sensitivity analysis during simulation. For example, assume that an approximated relationship is linear with a certain slope. This slope can be varied during succeeding simulation runs. It may be that the slope can vary within a wide range of values without affecting the simulation results in any significant way; this would indicate that a more precise formulation of the relationship is not needed. On the other hand, simulation results may be quite sensitive to a change in slope; in this case, it would be necessary to determine the true relationship precisely through further research. It is possible that a hypothesized relationship between two operationally defined variables cannot be shown to exist. In this case, the relationship could be removed from the model. This entire process of operationally defining variables and supporting hypothesized relationships comprises internal validation. After the model is internally validated, it should show the logic and consistency necessary for a good system simulation. The internally validated model also allows drawing of the final flow diagram and writing of equations.

Equations

There are a number of computer programs available which can accept a system of equations and produce the behavior of that system over time. Among these is DYNAMO, which handles continuous models. DYNAMO equations may be written directly from the flow diagram and a summary of relational data (20:1).

DYNAMO equations may be classified into six categories, including level (L), rate (R), auxiliary (A), constant (C), initialization (N), and supplementary (S). Where appropriate, time is indicated by the postscripts J for past, K for present, and L for future. At any moment K, the past is an incremental DT time units ago, while the future is DT time units forward (20:21-22; 8:73-79).

A typical level equation might be written as:

$$L.K = L.J + DT * (IR.JK - OR.JK)$$

That is, the present level equals the past level plus the difference between input and output rates over a given time period (8:76).

A typical rate equation might be written as:

$$OR.KL = (L2.K + L.K)/CONST$$

That is, the rate for the next DT time units depends on two current levels and a constant (8:78).

Auxiliary equations can be used to combine variables in any logical fashion and are used to simplify rate equations or isolate quantities common to more than one rate equation. Constant equations assign a constant value to a quantity, usually as input parameters. Initialization equations specify the initial value of a quantity. Finally, supplementary equations are used to compute values for output only (8:78-79).

See Figure 11 for a listing of equations for Sector I. Refer to Pugh (20) for a more detailed explanation of DYNAMO equations. After all equations for the model were written, the external validation phase of the modeling process began.

External Validation and Analysis

External validity is measured by a model's ability to reproduce the behavior of the simuland. Therefore, external validation is accomplished by comparing simulated behavior to system behavior, information about which can be gathered from the same sources noted in "Obtaining Relational Data" above. If the simulated behavior varies significantly from that of the system, the model requires modification until the difference between its behavior and system behavior falls within acceptable tolerances. These tolerances can only be subjective and of the same nature as the general qualitative relationships which are of necessity, inherent in the model. The first test of a model

```
A USF.K(I2)=USFC.K(I2)+SUMV(USFO.K(*,I2),1,NCNTRY)                1-1
L USFO.K(I1,I2)=USFO.J(I1,I2)+DT*(USFODR.JK(I1,I2)-
X USOFRR(I1,I2))                                                  1-2
N USFO(I1,I2)=USFOI(I1,I2)                                        1-2-1
T USFOI(*,1)=7350/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/
X 0/0/0/0/0/0/0/0/0/0/0/0                                         1-2-2
T USFOI(*,2)=265/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/
X 0/0/0/0/0/0/0/0/0/0/0/0                                         1-2-3
T USFOI(*,3)=515/0/0/72/0/0/0/144/0/96/0/0/0/0/0/0/0/0/0/
X 0/0/0/0/0/0/0/0/0/0/0/0                                         1-2-4
T USFOI(*,4)=0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/
X 0/0/0/0/0/0/0/0/0/0/0/0                                         1-2-5
L USFC.K(I2)=USFC.J(I2)+DT*(FDRTUS.JK(I2)-
X SUMV(USFODR.JK(*,I2),1,NCNTRY)-USCFRR.JK(I2))                   1-3
N USFC(I2)=USFCI(I2)                                              1-3-1
T USFCI=0/401/1307/176                                            1-3-2
R USOFRR.KL(I1,I2)=MAX(DELAY3(USFODR.JK(I1,I2),USFL(I2)),0)       1-4
T USFL=5/15/10/5                                                  1-4-1
R USCFRR.KL(I2)=DELAY3(FDRTUS.JK(I2)-SUMV(USFODR.JK(*,I2)
X ,1,NCNTRY),USFL(I2))                                            1-5
R USFODR.KL(I1,1)=MIN((MAX(0,(AMAXXX(NFN.K(I1,1,*),NCNTRY,I1)-
X RF.K(I1,1)-USFO.K(I1,1)))*MIN(USIROU(I1),ROWIUS(I1))),
X ((USF.K(1)*OSFRAC(1))-SUMV(USFO.K(*,1),1,NCNTRY)))              1-5A
A NFN.K(I1,I2,I3)=NF.K(I1,I2,I3)*RHOST(I1,I3)                     1-5A-1
R USFODR.KL(I1,2)=MIN(((ROWFR(I1)-SUMV(RF.K(I1,*),1,4)-
X SUMV(USFO.K(I1,*),1,4)-USFODS.K(I1,1))*MIN(USIROW(I1),
X ROWIUS(I1))),(SUM(USFTO)-SUM(USFO)))                            1-5B
A USFTO.K(I2)=USF.K(I2)*OSFRAC(I2)                                1-5B-1
A USFODS.K(I1,1)=MIN((MAX(0,(AMAXXX(NFN.K(I1,1,*),NCNTRY,I1)-
X RF.K(I1,1)-USFO.K(I1,1)))*MIN(USIROW(I1),ROWIUS(I1))),
X ((USF.K(1)*OSFRAC(1))-SUMV(USFO.K(*,1),1,NCNTRY)))              1-5B-2
R USFODR.KL(I1,3)=0                                               1-5C
R USFODR.KL(I1,4)=0                                               1-5D
T RHOST(*,1)=0/0/0/.5/0/1/0/0/1/0/1/.2/.2/.4/.4/0/.5/1/1/0/
X 0/0/0/.8/0/0/.2/0/.5/1/1/0/0                                    1-5-1
T RHOST(*,2)=0/1/1/0/0/1/1/1/0/0/1/0/0/0/0/0/.5/0/0/0/
X .5/.5/.5/1/1/.5/1/1/1/3/3/0/.7                                  1-5-2
T RHOST(*,3)=1/1/1/0/0/1/1/0/0/1/0/0/0/.5/0/0/.5/0/0/0/
X 0/.5/.8/.5/.2/0/1/0/0/0/0/0/0                                   1-5-3
T RHOST(*,4)=0/0/0/0/0/.5/1/0/0/0/0/0/0/0/0/.7/0/0/0/
X 0/0/.5/0/.6/0/0/0/0/.3/.3/0/0                                   1-5-4
T RHOST(*,5)=0/0/0/0/0/1/1/0/0/0/0/0/0/0/0/0/0/0/0/
X 0/0/0/0/1/0/0/0/0/0/0/0/0                                       1-5-5
T RHOST(*,6)=0/0/0/0/0/0/.5/0/0/0/0/0/0/0/0/0/0/0/0/0/
X 0/0/0/0/0/0/0/0/0/0/0/0/0                                       1-5-6
T USIROW=1/1/1/1/1/0/.2/1/.8/.3/0/0/0/0/0/0/.4/0/.3/0/0/
X 0/0/.3/0/.6/1/0/.2/0/0                                          1-6-1
T OSFRAC=1/.33/.33/.33                                            1-6-2

NOTE
CFPUS      COMPLETED FORCE PRODUCTION BY US
EUSBT      EFFECT ON US BALANCE OF TRADE
FDRTUS     FORCE DEPLOYMENT RATE BY THE US
I1         COUNTRY ARRAY
I2         FORCE ARRAY
I3         NEIGHBOR ARRAY
I4         COUNTRIES NOT EXEMPT FROM THE CEILING ARRAY
I5,I6      ALLOW SOVIET UNION TO ORDER NUCLEAR WEAPONS
NCI        NUMBER OF COUNTRIES INCLUDING US
NCNTRY     NUMBER OF COUNTRIES
NFN        NEIGHBOR THREAT TO REST OF WORLD
OSFRAC     OVERSEAS DEPLOYMENT FRACTION
RF         REST OF WORLD FORCE INVENTORY
RHOST      PERCEIVED REST OF WORLD HOSTILITY TO REST OF WORLD
ROWFR      REST OF WORLD FORCE REQUESTED
ROWIUS     REST OF WORLD IMPORTANCE TO THE US
USCFRR     US CONUS FORCES RETIREMENT RATE
USF        US FORCE INVENTORY
USFC       US FORCES IN CONUS
USFCI      US FORCES IN CONUS - INITIAL LEVEL
USFL       US FORCE LIFE
USFO       US FORCES OVERSEAS
USFODR     US FORCES OVERSEAS DEPLOYMENT RATE
USFODS     US FORCES OVERSEAS DEPLOYMENT RATE-INTERIM VALUE
USFOI      US FORCES OVERSEAS-INITIAL LEVEL
USFRRT     US FORCE REQUEST RATE
USFTO      MAXIMUM US FORCES DEPLOYABLE OVERSEAS
USIROW     US IMPORTANCE TO THE REST OF WORLD
USOFRR     US OVERSEAS FORCES RETIREMENT RATE
USPCFA     US PRESSURE ON CONGRESS FOR FORCE APPROPRIATIONS
USPSFA     US POPULAR SUPPORT FOR FORCE APPROPRIATIONS
```

Fig. 11. Equations, Sector I

is to ensure that its behavior is not implausible. Certain flows must be unidirectional, and values of variables must fit practical ranges. Further tests may include running the model with inputs covering an unusually wide envrion-mental range. "A breakdown of the model policies under reasonable crisis tests often reveals defects that effect model performance even in more normal circumstances [8:119-120]." After internal and external validation have been accomplished, analysis of different arms transfer policies can begin.

Influence diagramming, operational definition of variables, flow diagramming, and DYNAMO equation writing were discussed in this chapter. In addition, the concepts of internal and external validation, and model analysis were addressed. The influence diagram of the U.S. Military Resources Sector was presented, and was transformed into a flow diagram and equations.

Chapter IV completes a full verbal description of the system and develops the influence diagrams for the remaining nine sectors. Chapter V contains the flow diagrams for the entire model and describes the equations used by the computer. Chapter VI contains the researchers' conclusions, recommendations and suggestions for further research.

CHAPTER IV

CONCEPTUAL DEVELOPMENT OF THE MODEL

Chapter I contained an introduction to the arms transfer system, the problem statement for this study, and a list of research questions. Chapter II embraced a literature review of related material and established that the arms transfer process could be modeled. Chapter III included a description of the system in terms of political, economic, and military segments, and a methodology for modeling the system using the DYNAMO computer language.

The first step in this methodology was to develop influence diagrams from a verbal description of the system using knowledge gained from the literature review. The development of the U.S. Military Resources Sector (I) was presented as an example. This chapter comprises a description of how the same methodology was applied to produce influence diagrams for the remaining nine sectors.

U.S. Financial Sector (II)

The U.S. Financial Sector contains most of the policy structure for relevant U.S. financial decisions. The source of funds for the U.S. defense system is the Defense Appropriation Fund which receives its dollars as

a result of Congressional action. The pressure on the Congress to increase defense appropriations is a complex blend of political, economic and military factors. Those considered significant to the arms transfer system are depicted in Fig. 12 and include Popular Support for Defense Spending, Requested Arms for DOD, threat (direct and indirect) to the U.S., U.S. Military Capabilities and Lobbying Effort for Arms Production.

The dollars which eventually find themselves in the Defense Appropriation Fund originated from Tax Revenue and are, therefore, a function of Gross National Product as well as Pressure on Congress for Defense Dollars. Competing for the Tax Revenue is Other Appropriated Funds which, in turn influences Popular Support for Defense Spending. This completes a negative loop and depicts how the demands for other appropriations prevent the Congress from spending all of the Tax Revenue on defense.

For the purposes of this system all of Defense Appropriation Fund is disbursed as Payments for Defense Production. Also acting to satisfy U.S. Industry Demand for Payments are payments for arms produced for overseas countries. These are metered out to the industry by the USG through the Trust Fund. The Trust Fund receives its dollars from customer countries through a variable defined as U.S. Trade Surplus. All payments combine to contribute to the profitability of the defense industry.

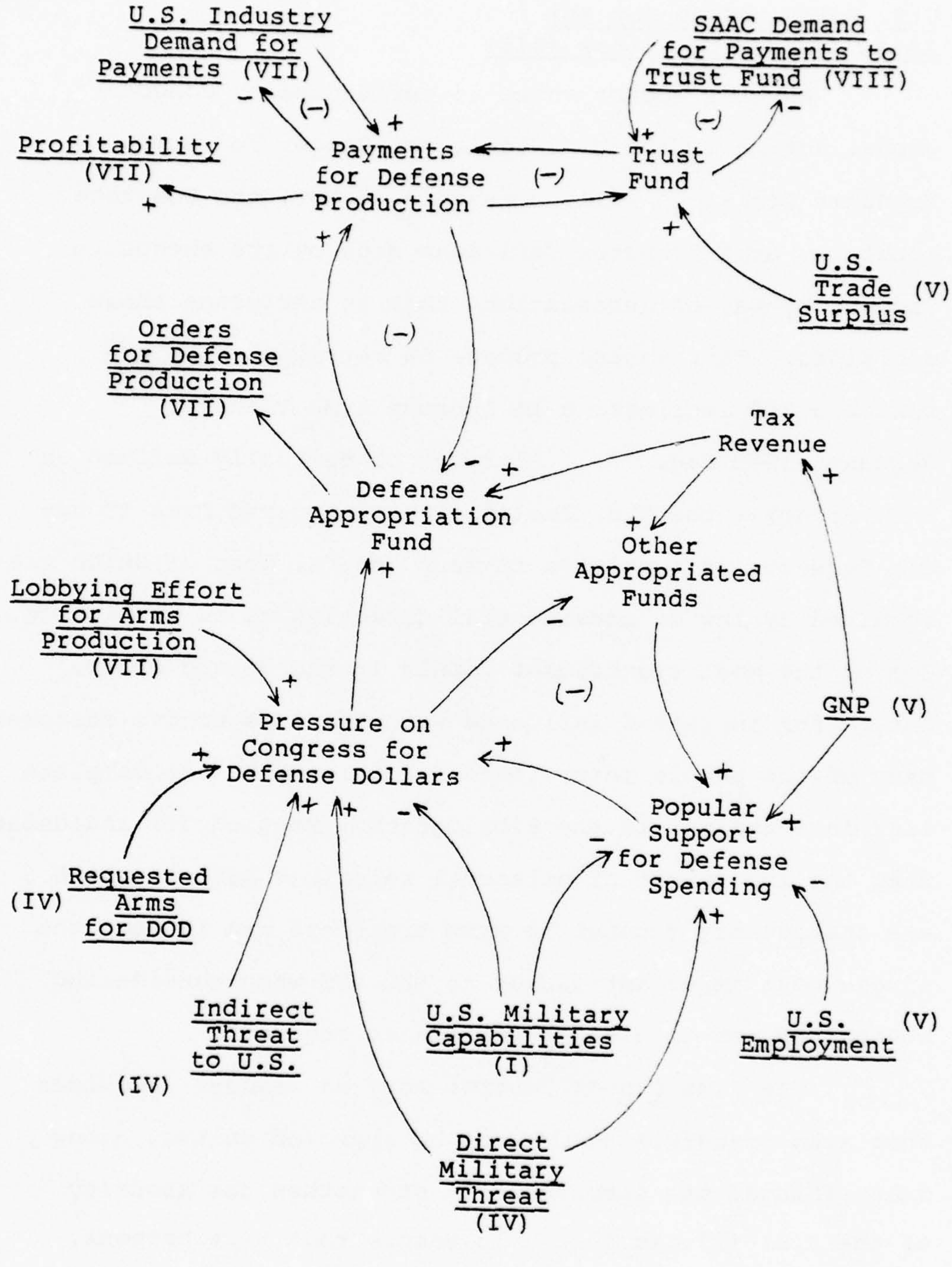

Fig. 12. U.S. Financial Sector (II)

U.S. Political Sector for
Arms Transfer Decisions (III)

Another sector which is influenced by Congressional action is the U.S. Political Sector for Arms Transfer Decisions (III). In this sector, the Congress monitors arms transfer decisions made by the executive and is, by way of legislation, able to influence those decisions. This entire process is represented by the variable U.S Inclination to Approve Arms Transfer Requests (See Fig. 13). Although conceptually defined as one variable, the U.S. Inclination to Approve Arms Transfer Requests is sensitive to many inputs, most of which are required by law or presidential directive to be considered. One of the most significant inputs is the United States' desire for increased influence with the prospective customer. Many of the people interviewed for this work (the complete list is contained in the Bibliography, Section II) indicated that the importance of bilateral relations between the U.S. and the country requesting arms transfers was in fact the single most important factor to the USG when considering whether or not to disapprove a sales request.

The Arms Export Control Act, as amended, requires that arms transfers would not be approved unless, among other things, the transfer will strengthen the security of the U.S. (27:Sec.102). To ensure that this happens, information about threat to the U.S. (direct and indirect)

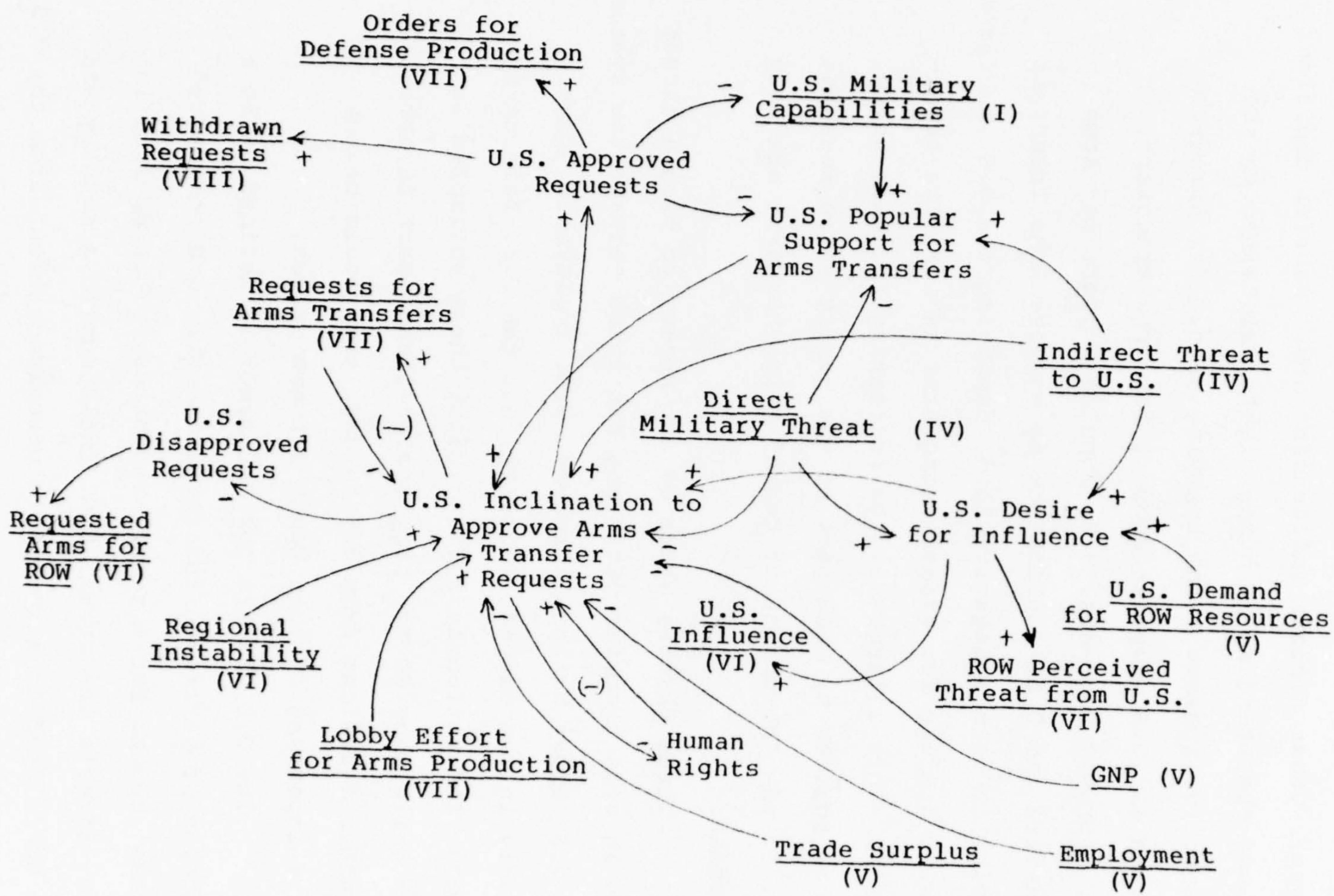

Fig. 13. U.S. Political Sector for Arms Tranfers Decisions (III)

and regional instability needs to be studied by decision makers. Other factors influencing arms transfer decisions include the standard of human rights maintained by the prospective customer, the Lobbying Effort for Arms Production and U.S. Popular Support for Arms Transfers. U.S. Approved Requests, U.S. Popular Support for Arms Transfers and U.S. Inclination to Approve Arms Transfers combine to form a negative loop, depicting the U.S. public's growing dislike for transferring arms as more are transferred. This illustrates the increasing pressure which can be applied by that part of the public which sees the U.S. in the "Merchants of Death" role when arms are sold overseas.

Three factors which do not appear to play a direct role in arms transfer decisions but which pervade the system are U.S. Gross National Product, U.S. Employment, particularly in the defense industry, and the U.S. balance of trade. The rationale for including these variables is that while they do not play a significant part in arms transfer decisions from day to day, they could become quite important if they reach extreme values.

The U.S. Desire for Influence is defined to be a function of perceived threat to the U.S. and the United States' demand for external resources. This desire, in turn, affects the actual U.S. influence in a country and can be related to a country's perceived threat from the U.S.

Requests for arms transfers which are denied by the political machinery remain in the system and are returned to the requesting country for re-assignment.

One of the most important inputs to this sector is information about threats to the United States. Sector IV., the U.S. Military Resource Planning Sector, considers those factors which can combine to threaten the U.S. for the purpose of defining direct and indirect threat to U.S.

U.S. Military Resource Planning Sector IV

Direct Military Threat is a combination of military capabilities and aggressive intentions toward the U.S. by a country or group of countries. It implies a risk of overt attack on U.S. property. The degree of direct threat felt by the people of the U.S. will influence United States' required capabilities, U.S. desire for influence, particularly with friendly countries and the popular support for defense spending. These influences, in turn, increase the pressure on Congress for defense dollars. This process is depicted in Figure 14. An Indirect Threat to the U.S. is more subtle than a direct military threat and can involve U.S. interests in foreign countries being jeopardized. In this sense the possibility of being unable to import crude oil as a result of unrest in an area might constitute an indirect military threat to

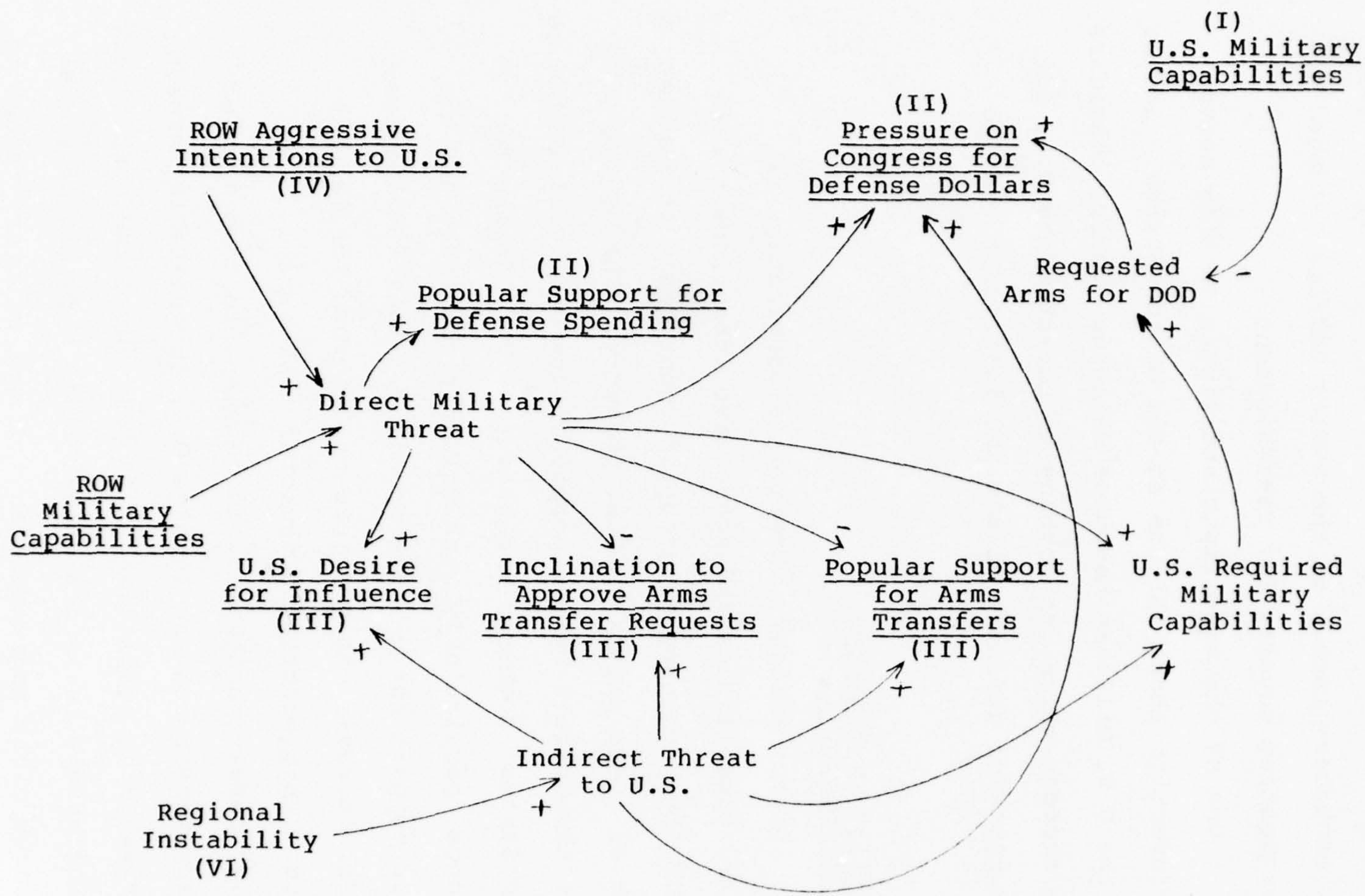

Fig. 14. U.S. Military Resources Planning Sector (IV)

the U.S. In other words, all threats against the U.S. which are not direct and which might require military intervention are compounded in the variable, Indirect Threat to U.S. This indirect threat is considered to be a function of regional instability.

Although an indirect threat may not be as visible as a direct threat, the process by which it results in increased Pressure on Congress for Defense Dollars is, for the purposes of this study, the same. The effect of direct military threat on the arms transfer system is, however, different from that of an indirect threat. In the general sense, as the direct threat to the U.S. increases, so she would be more likely to concentrate on devoting her defense production towards enhancing her own military capabilities. On the other hand, as indirect threat is perceived to increase, the U.S. is more likely to transfer arms to friendly countries in the region concerned so as to reduce the magnitude of possible U.S. military involvement (for example, the U.S. increased arms transfers to South Korea partly so that she could reduce her own commitment there). In Figure 14 this is depicted as a negative influence line from Direct Military Threat to Inclination to Approve Arms Transfer Requests while the arrow from Indirect Threat to U.S. is positive.

The next sector to be considered is the U.S. Economic Sector.

U.S. Economic Sector (V)

While the U.S. economy is not thought to play an important part in arms transfer decisions, the ability of U.S. industry to produce arms is quite important. If the rate of growth in GNP is high, U.S. employment stable, and the balance of trade close to zero, then the economy can be considered healthy. Under these conditions the arms industry can expand its capacity, develop new weapons systems, and plan its production smoothly.

If conditions departed significantly from this norm, arms transfer decisions may be more influenced by economic events through changing lobby group activity, pressure on the Congress and through popular support for arms production and arms transfers. These relationships are depicted in Figure 15.

Arms transfer decisions do have a small effect on the economy. Arms production contributes in a positive way to GNP and employment while arms transfers enhanced the U.S. Trade Surplus position. Also in this sector and detracting from the trade position to some extent is the Cost of Maintaining Forces Overseas. All things considered, the U.S. economy has a small but important impact on the arms transfer system which, through a feed-back process, influences the economy.

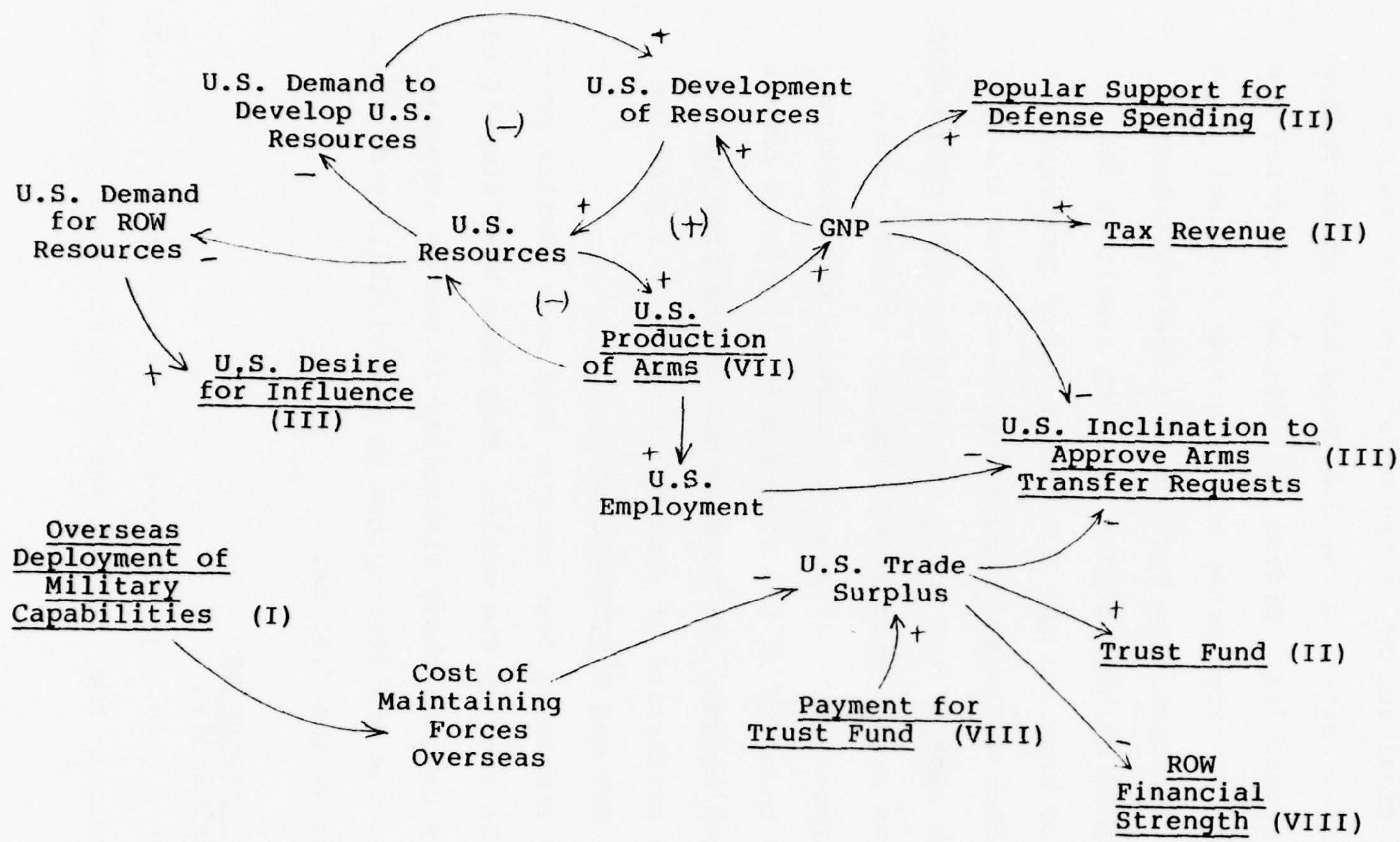

Fig. 15. U.S. Economic Sector (V)

U.S. Arms Production Sector VII

The final sector of the model concerned mainly with the United States is the U.S. Arms Production Sector (VII) (See Figure 16). Orders for Defense Production are received from DOD when money has been made available from the Defense Appropriation Fund or from the Trust Fund. Orders accepted by the defense industry result in the production of arms for the U.S. and foreign customers. Arms production depletes resources obtained from the U.S. and from the rest of the world and utilizes U.S. production capacity. An excess production capacity coupled with a profitable position results in increased lobby activity by the arms industry in the Congress for increased orders from home and abroad. As pointed out in the previous sector, the production of arms contributes in a positive way towards GNP and U.S. Employment.

The remaining four sectors deal with similar processes in the rest of the world. They have been simplified conceptually because their visibility is not so important to the U.S. arms transfer system as the visibility of their counterparts in the U.S. is.

ROW Military Resources Planning Sector (VI)

From a very high view-point, the process for foreign countries to plan for, request and authorize arms procurement

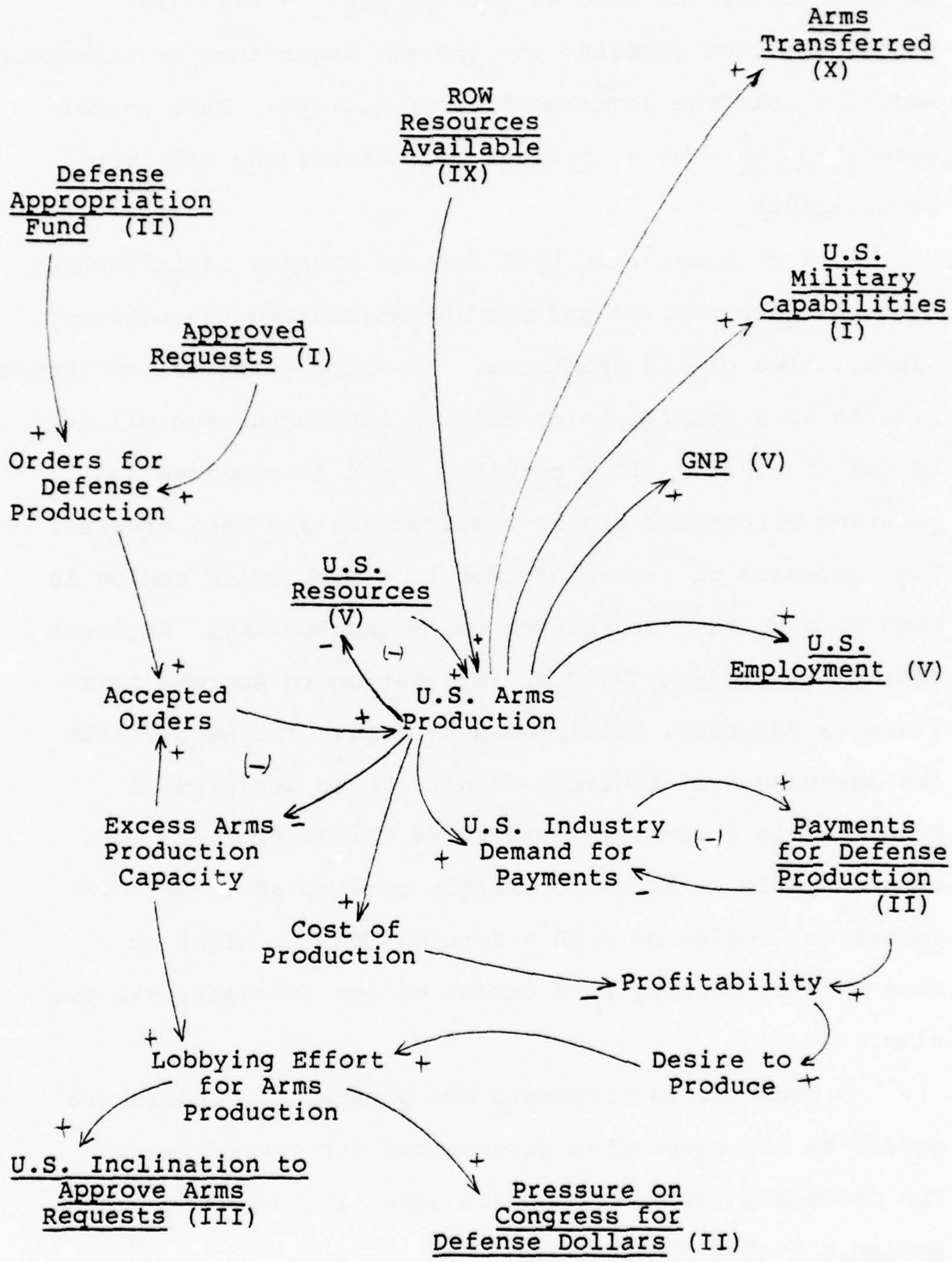

Fig. 16. U.S. Arms Production Sector (VII)

is essentially the same as for the U.S. A military planning sector assesses the threat, determines requirements, and then asks the government for resources. This sector describes the general process for determining military requirements.

The threat felt by a foreign country is influenced by both the perceived hostile intentions and the military capabilities of its neighbors. An examination of the threat results in a country being able to determine what military forces it needs. This required force is compared to existing forces and excess requirements are then ordered. The aggregate of requested arms in a particular region is used as a measure of that region's instability. Regional instability impacts the U.S. Inclination to Approve Arms Transfer Requests, willingness to deploy forces overseas and assessment of indirect threat. Also depicted in Figure 17 is a country's perceived threat from the U.S. This variable is shown separately because an active U.S. desire for influence with a foreign country might be seen by that country as a threat to its international position.

Once the requirements are determined, orders are passed to the respective governments for consideration. The processes involved here are shown in the ROW Politico-Economic Sector (VIII).

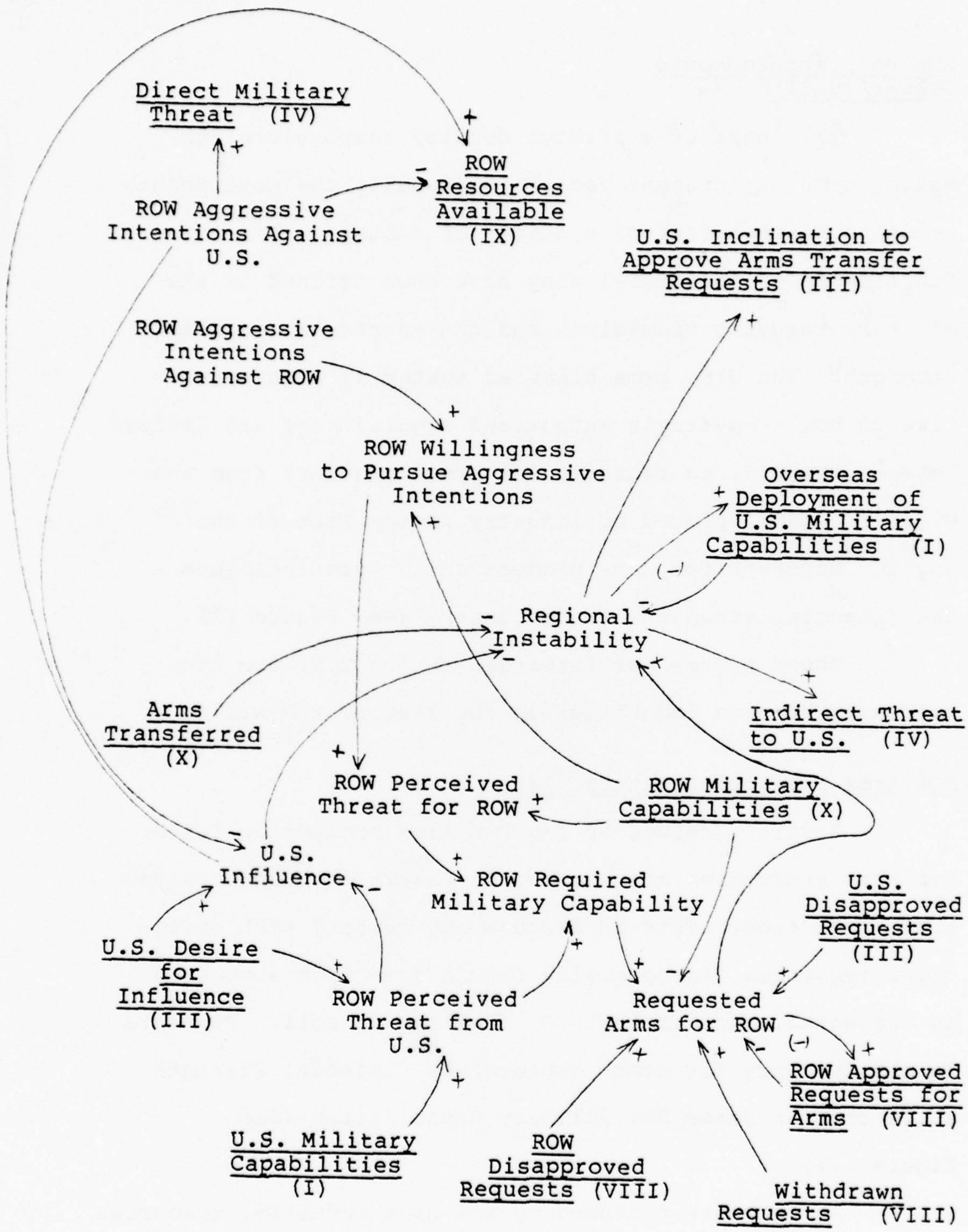

Fig. 17. ROW Military Resources Planning Sector (VI)

ROW Politico-Economic Sector (VIII)

That part of a foreign country responsible for making arms procurement decisions (usually the government) needs to be cognizant of a number of factors. For the functioning of this model they have been defined as the military requests themselves and the country's financial strength. The U.S. arms transfer system is then sensitive to how a country's authorized acquisitions are divided between the U.S. as requests for arms transfers from the U.S. and orders placed to industry in the rest of the world. Payments for arms production in turn influence the financial strength of the country (See Figure 18).

Those orders not forwarded to the U.S. are then processed by arms industries in the rest of the world.

ROW Arms Production Sector (IX)

Orders received by the ROW Arms Production Sector for arms production are assumed to result in unconstrained arms production. This is because any country with sufficient resources can generally obtain arms from somewhere in the world, even if the U.S. declines to sell. Payments to the industry for arms deplete ROW Financial Strength while they increase ROW Military Capabilities (See Figure 19).

As arms are produced by the arms industry, resources are depleted and this in turn reduces the total resources

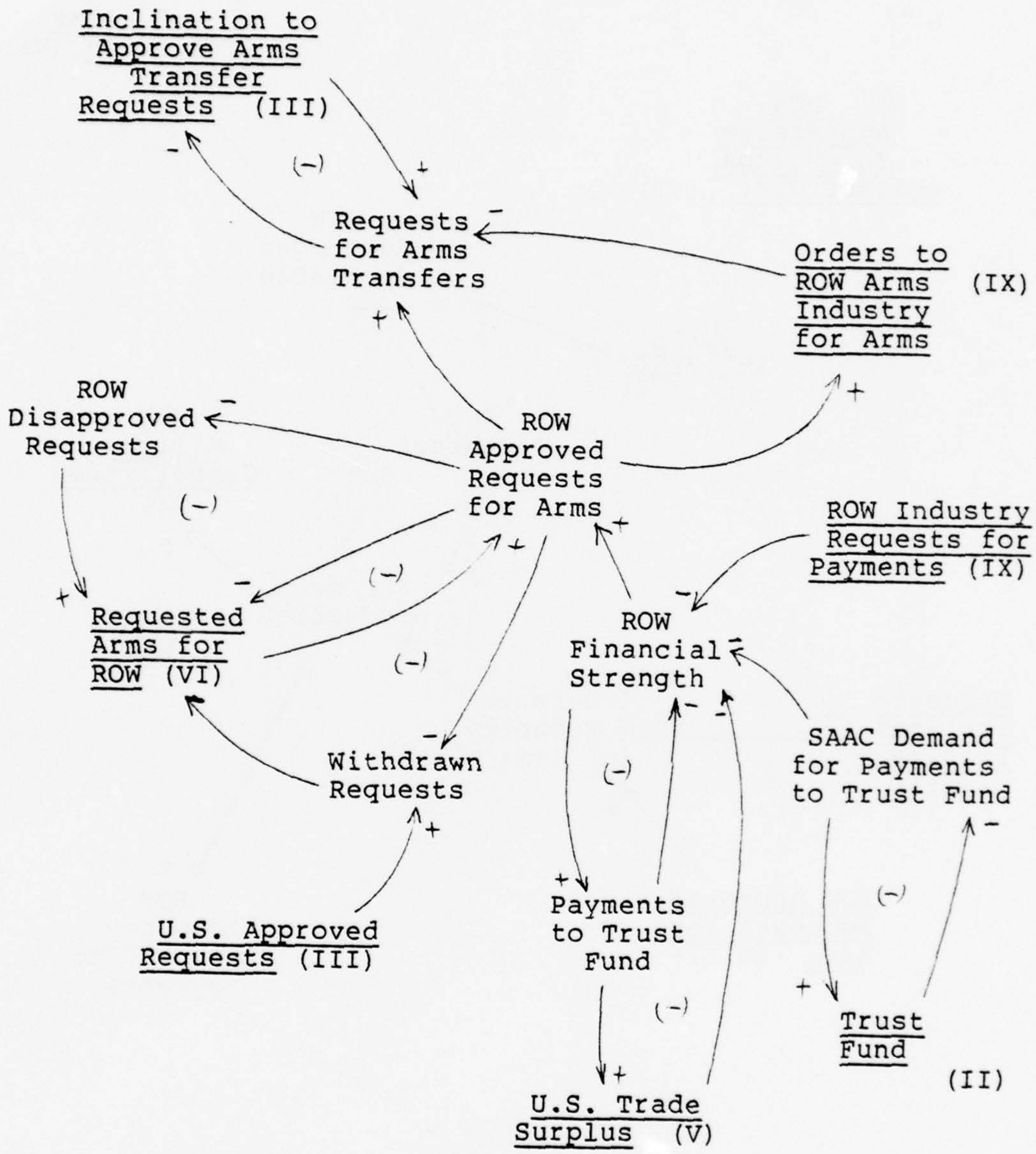

Fig. 18. ROW Politico-Economic Sector (VIII)

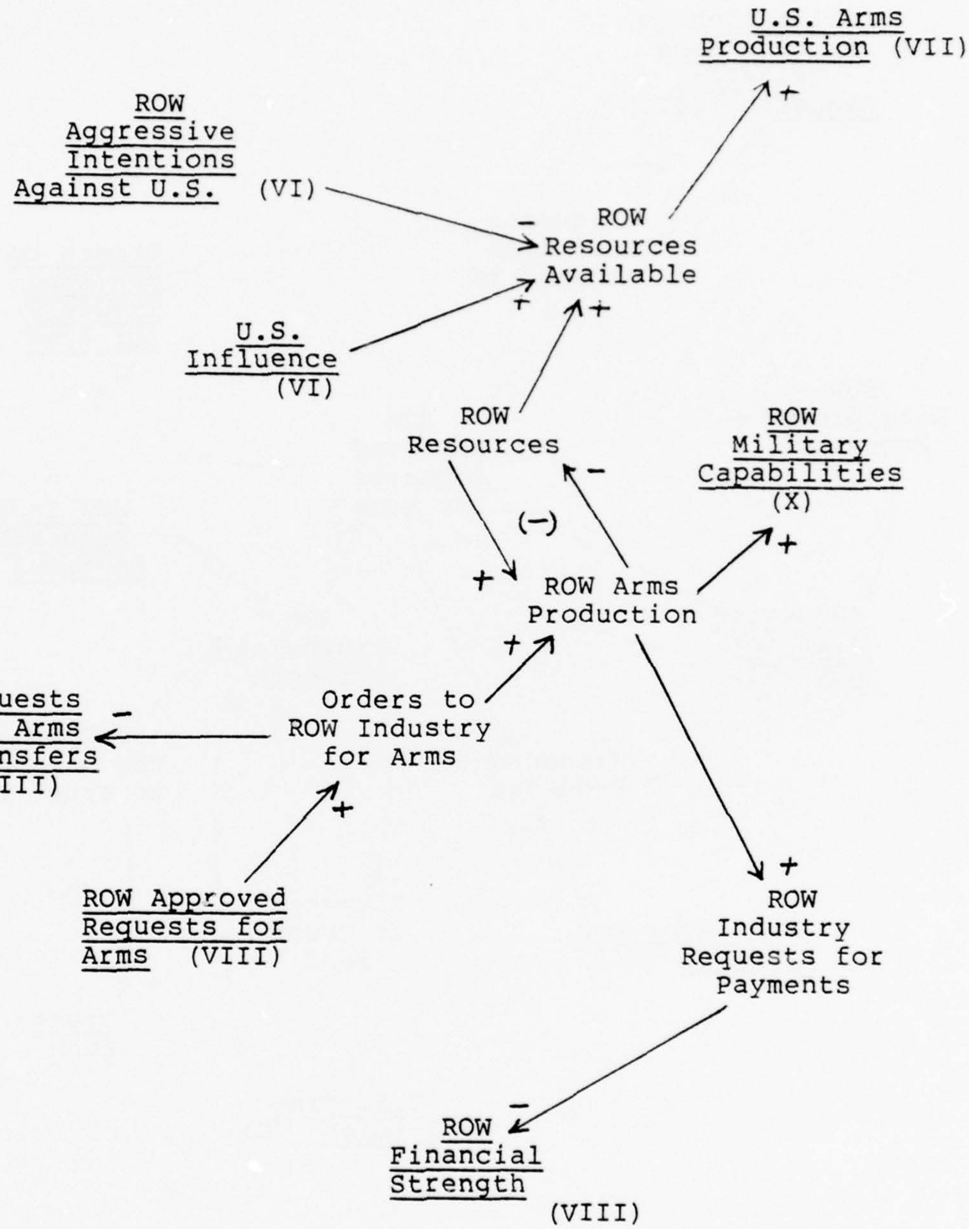

Fig. 19. ROW Arms Production Sector (IX)

available in the world. Available resources are sensitive to some extent to U.S. influence as well, both for their development and depletion.

The final sector to be considered in the development of the arms transfer system model is the ROW Military Resources Sector. If aggressive intentions against the U.S. increase, the U.S. opportunity to develop overseas resources declines.

ROW Military Resources Sector (X)

This sector is conceptually very simple and demonstrates how arms from U.S. Production Sector contribute to Arms Transferred. Arms Transferred combined with ROW Arms Production to produce the total increase in ROW military Capabilities (See Figure 20).

Transferred arms generally reduce the Overseas Deployment of U.S. Military Capabilities and Regional Instability. An increase in ROW Military Capabilities on the other hand increases the overall threat to the U.S. and the ROW's willingness to pursue aggressive intentions. It also depletes the number of requested arms for countries concerned.

Summary

This chapter has finished the conceptual development of the arms transfer system model and completed the

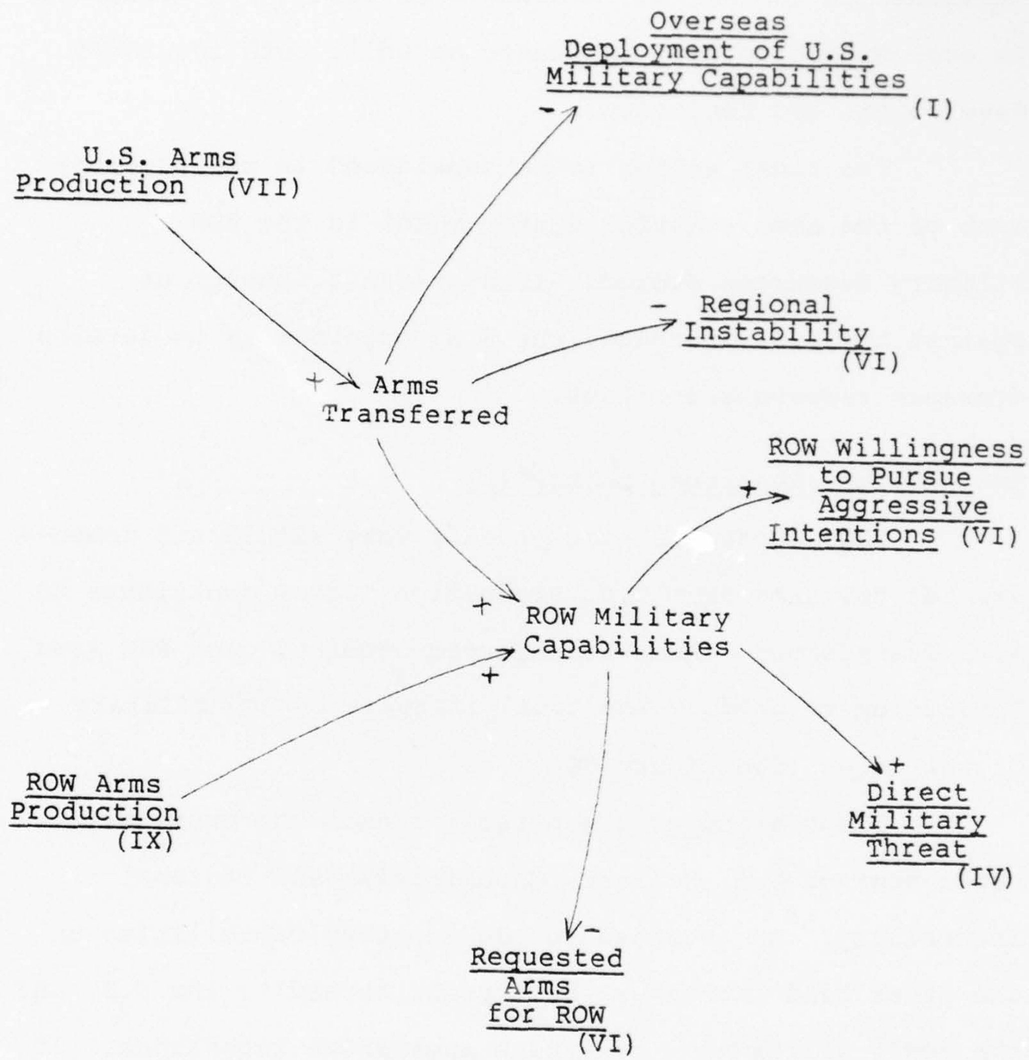

Fig. 20. ROW Military Resources Sector (X)

development of the influence diagrams. The next stage in the development of a model of the arms transfer system involves operationally defining the variables in the influence diagrams and then depicting the relationships between those variables in terms of levels and flows of capital, arms, orders and dollars. The entire array of flows and rates will be linked together by channels of information to form a flow diagram. Chapter V contains the completion of the flow diagrams and the equation development necessary for running the model on the computer. Chapter VI contains a summary of the research effort, conclusions, and recommendations for further research.

CHAPTER V

DEVELOPMENT OF THE FLOW DIAGRAMS AND EQUATIONS

Sector I of the arms transfer model was completely presented in Chapter III. In the previous chapter, the conceptual framework of the other nine sectors was developed. In this chapter, the flow diagrams and equations for the other nine sectors are presented. The sector diagrams were developed from the conceptaul model and information gathered during the literature search and interviews. This chapter contains not only a description of the technical structure of the model but presents a discussion of much of the rationale behind its structure and development.

For each sector or subsector (manageable fraction of a sector), the major flows will be traced in narrative form. The flow diagrams and equations will be presented in separate figures. Additionaly, due to the complexity involved, the significant rates and auxiliaries will be explained in separate tables. Before beginning the explanation of the flow diagrams, the conventions employed in the model will be discussed.

Conventions

The conventions employed in the model pertain to countries, weapon technologies, typical weapon systems, and units.

Although all 150-plus countries in the world could have been included in the model, this level of detail was not required to portray the dynamic behavior of the system. Therefore, the countries of the world excepting the United States were aggregated or averaged into 31 countries. Where several countries could be considered as one, their characteristics were aggregated. Where countries could not be aggregated due to political or other considerations, but were essentially similar, their characteristics were averaged. Additionally, a dummy country (with no forces, no Gross National Product [GNP], no enemies, etc.) was defined as country 32. The U.S. is country 33. (See Appendix B for a list of countries.)

Weapons systems in the model were segregated into four technological categories: Nuclear, state-of-the-art, modern, and dated. Classification of a weapon system into one of the latter three categories was based on the following criteria: State-of-the-art equipment was deployed after 1970, modern between 1960 and 1970, and dated before 1960.

Rather than attempt to represent in the model all of the different weapons systems in deployment, the authors chose two typical ones: Tactical nuclear weapons and tactical combat aircraft. Tactical nuclear weapons were included because their presence can influence the composition of conventional forces. Note that the dividing dates

between technological categories are somewhat dependent on the choice of tactical combat aircraft as the typical system. These dates may require adjustment should a different typical system be chosen.

Finally, material flows in the model are denominated in units of aircraft or nuclear weapons; order flow in orders for the same; and capital flows in units of capital required to produce the same. All dollar flows and amounts are denominated in hundreds of millions of constant 1972 U.S. dollars, except for GNP per capita amounts, which are in single dollars. Time is in years. Values and sources for constants and initial conditions are given in Appendix C.

Having explained the conventions used in the model, the remaining sectors and subsectors can be described.

Sector 0.

The equations for this sector are shown in Figure 21. Sector 0 contains a number of statements necessary for the operation of the model, including the Neighbor (NEIGH) array. The latter allows a country in the model to identify its neighbors. This identification is required for threat assessment.

Subsector II-A

The flow diagram for this subsector is shown in Figure 23 and the equations in Figure 22. U.S. Force

```
* ARMS TRANSFER MODEL
C NCNTRY=32                                                           0-1
C NCI=33                                                              0-2
T NEIGH(*,1)=2/1/1/6/10/1/4/4/7/4/7/13/12/15/14/12/14/19/18/
X 18/20/20/20/23/23/20/25/6/7/25/25/32/16                             0-3
T NEIGH(*,2)=3/3/2/7/32/2/6/7/32/5/10/16/16/16/16/13/15/
X 20/20/19/22/21/22/25/24/24/30/29/28/27/27/32/17                     0-4
T NEIGH(*,3)=6/6/6/8/32/3/8/32/32/11/32/32/32/17/32/14/16/32/
X 32/21/32/23/24/26/27/32/31/30/32/28/28/32/32                        0-5
T NEIGH(*,4)=32/32/32/10/32/4/9/32/32/32/32/32/32/32/32/15/
X 33/32/32/22/32/32/25/32/30/32/32/31/32/31/30/32/32                  0-6
T NEIGH(*,5)=32/32/32/32/32/7/11/32/32/32/32/32/32/32/32/17/
X 32/32/32/23/32/32/32/32/31/32/32/32/32/32/32/32/32                  0-7
T NEIGH(*,6)=32/32/32/32/32/28/29/32/32/32/32/32/32/32/32/
X 33/32/32/32/26/32/32/32/32/32/32/32/32/32/32/32/32/32               0-8
FOR I1=1,NCNTRY
FOR I2=1,4
FOR I3=1,6
FOR I4=6,NCNTRY
FOR I5=1,5/I6=7,32
N TIME=1979
FNCTN AMAX(2,0,1)                                                     0-9
FNCTN AMAXX(3,0,1)                                                    0-10
FNCTN AMAXXX(3,0,1)
FNCTN FIND1(6,0,11)                                                   0-11
FNCTN FIND2(5,0,11)                                                   0-12
FNCTN FIND3(6,0,111)                                                  0-13
```

Fig. 21. Equations, Sector 0

```
NOTE
R USFRPR.KL(I2)=DELAY3(USFRRT.JK(I2),USFRPD)                          2-1
C USFRPD=.75                                                          2-1-1
L USFRP.K(I2)=USFRP.J(I2)+DT*(USFRPR.JK(I2)-
X USFRAR.JK(I2)-USFRDR.JK(I2))                                        2-2
N USFRP(I2)=USFRPI(I2)                                                2-2-1
T USFRPI=0/0/0/0                                                      2-2-2
R USFRAR.KL(I2)=USPCFA.K*USFRP.K(I2)                                  2-3
R USFRDR.KL(I2)=(1-USPCFA.K)*USFRP.K(I2)                              2-4
NOTE
USART      US APPROPRIATION RATE
USFRAR     US FORCE REQUEST APPROVAL RATE
USFRDR     US FORCE REQUEST DENIAL RATE
USFRP      US FORCE REQUESTS PROCESSED
USFRPD     US FORCE REQUEST PROCESSING DELAY
USFRPI     US FORCE REQUESTS PROCESSED-INITIAL LEVEL
USFRPR     US FORCE REQUEST PROCESSING RATE
USFRRT     US FORCE REQUEST RATE
USPCFA     US PRESSURE ON CONGRESS FOR FORCE APPROPRIATIONS
USUO       US UNFILLED ORDERS
```

Fig. 22. Equations, Subsector II-A

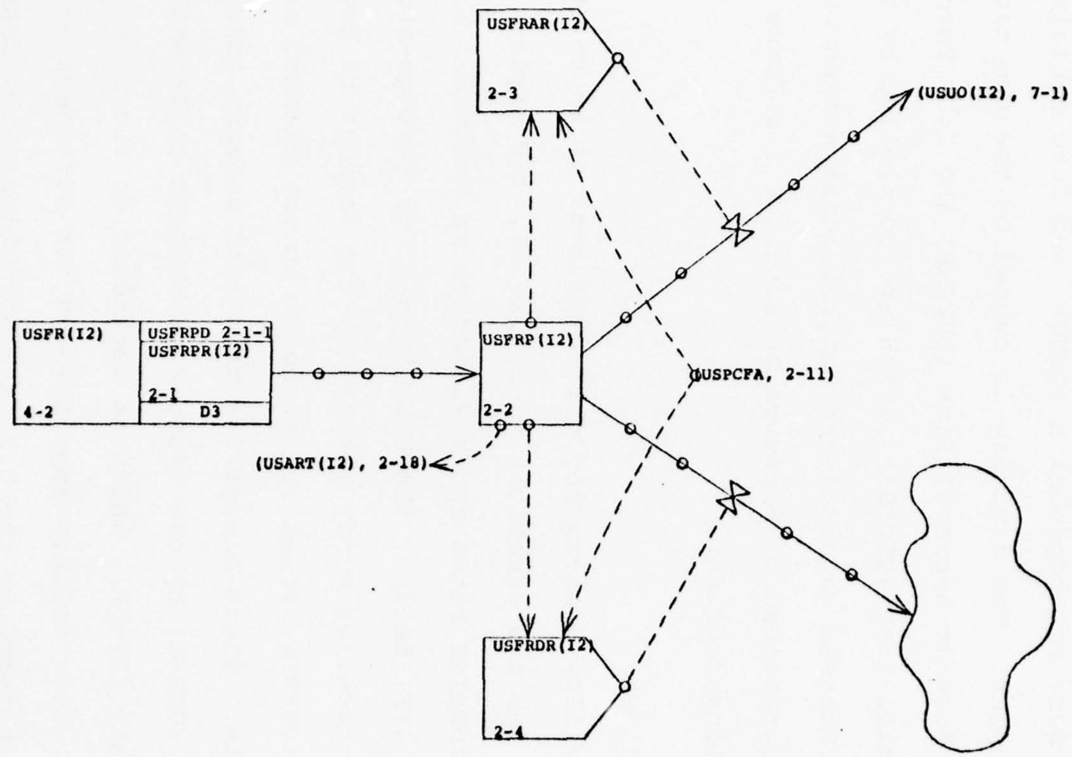

Fig. 23. Flow Diagram, Subsector II-A

Requests (USFR) from the Department of Defense are processed through an Executive and Congressional delay (USFRPR) to U.S. Force Requests Processed (USFRP). Processed requests are immediately divided into approved requests, which become unfilled orders for production (USUO), and into denials, which disappear. The division is caused by the two rates U.S. Force Request Approval Rate (USFRAR) and U.S. Force Request Denial Rate (USFRDR), which are controlled by the level of processed requests and Congressional action on requests represented by Pressure on Congress for Force Appropriations (USPCFA).

Subsector II-B

The flow diagram for this subsector is shown in Figure 24, and the equations in Figure 25, the explanation of complex rates and auxiliaries in Table 2. The Trust Fund (TF) held by the U.S. to pay for foreign-ordered production receives money metered by the Payment to Trust Fund Rate (PTFRT), which is dependent on the planned production rate. These monies are paid into defense industry treasuries (USDIL) by the Trust Fund Payment to Defense Industry Rate (TFPIR), which is dependent on the production rate. U.S. dollars appropriated for defense production (USFA) are metered by the U.S. Appropriation Rate (USART), which is essentially the same as USFRAR in Sector II-A. The U.S. Government pays industry via the U.S. Payment to

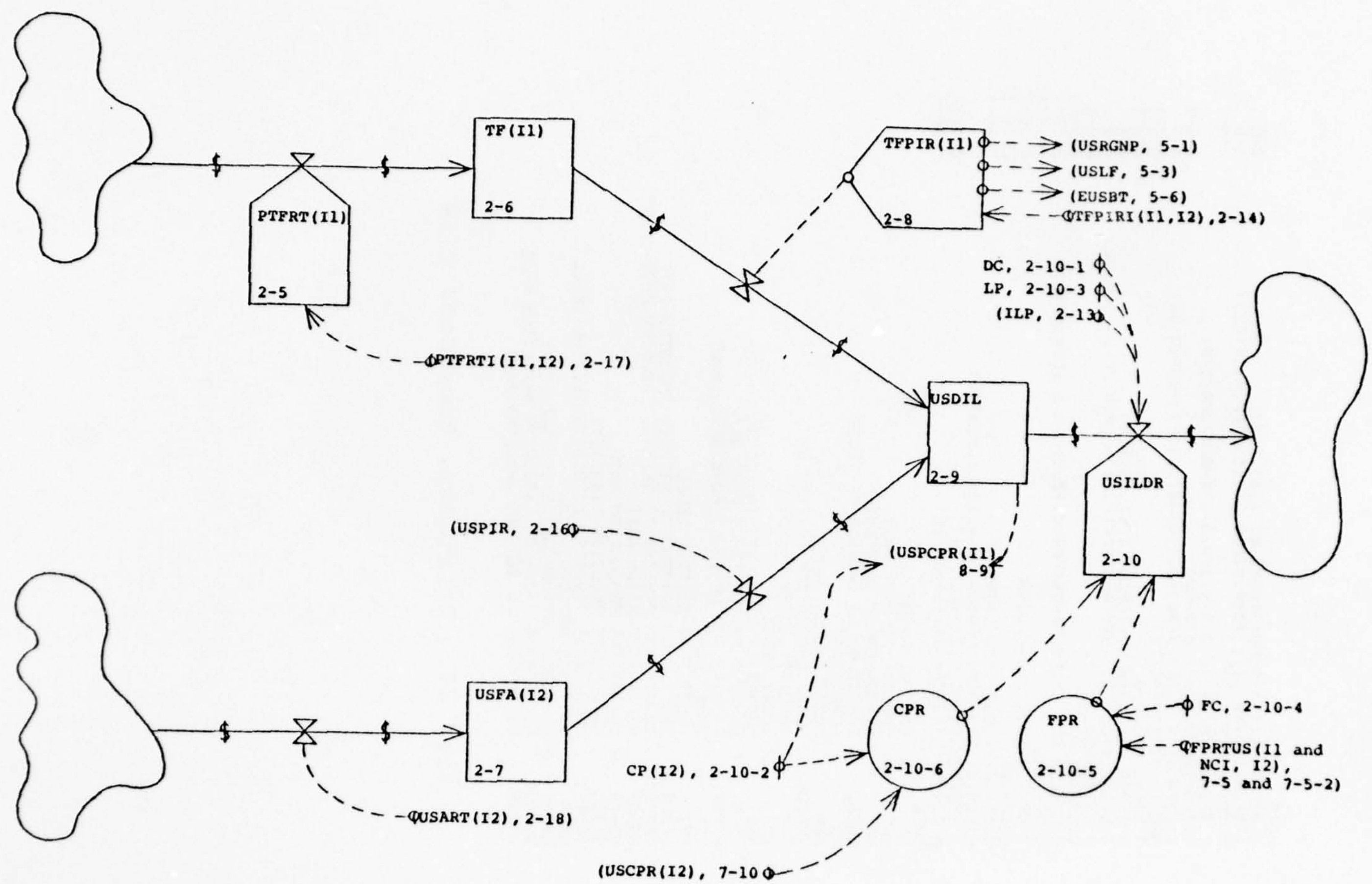

Fig. 24. Flow Diagram, Subsector II-B

```
NOTE
R PTFRT.KL(I1)=SUMV(PTFRTI.K(I1,*),1,4)                          2-5
L TF.K(I1)=TF.J(I1)+DT*(PTFRT.JK(I1)-TFPIR.JK(I1))               2-6
N TF(I1)=TFI(I1)                                                 2-6-1
T TFI=0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/
X 0/0/0/0/0/0/0/0/0/0/0                                          2-6-3
L USFA.K(I2)=USFA.J(I2)+DT*(USART.JK(I2)-USPIR.JK)               2-7
N USFA(I2)=USFAI(I2)                                             2-7-1
T USFAI=0/0/0/0                                                  2-7-2
R TFPIR.KL(I1)=SUMV(TFPIRI.K(I1,*),1,4)                          2-8
L USDIL.K=USDIL.J+DT*(SUM(TFPIR.JK)+USPIR.JK-USILDR.JK)          2-9
N USDIL=USDILI                                                   2-9-1
C USDILI=0                                                       2-9-2
R USILDR.KL=ILP.K*LP+SUM(FPR.K)+SUM(CPR.K)+DC*USDIL.K            2-10
C DC=.075                                                        2-10-1
T CP=.6/.2873/.124/.0359                                         2-10-2
C LP=.01                                                         2-10-3
T FC=.085/.068/.029/.0085                                        2-10-4
A FPR.K(I2)=(SUMV(FPRTUS.JK(*,I2),1,NCNTRY)
X +FPRTUS.JK(NCI,I2))*FC(I2)                                     2-10-5
A CPR.K(I2)=USCPR.JK(I2)*CP(I2)                                  2-10-6
NOTE
CP        CAPITAL PRICE
CPR       CAPITAL PAYMENT RATE
DC        DISBURSEMENT CONSTANT
EUSBT     EFFECT ON US BALANCE OF TRADE
FC        FORCE COST
FPR       FORCE PAYMENT RATE
FPRTUS    FORCE PRODUCTION RATE BY US
ILP       INDUSTRY LOBBY PRESSURE
LP        LOBBY PRICE
NCI       NUMBER OF COUNTRIES INCLUDING THE US
PTFRT     PAYMENT TO THE TRUST FUND RATE
PTFRTI    PAYMENT TO THE TRUST FUND RATE-INPUT
TF        TRUST FUND
TFI       TRUST FUND-INITIAL LEVEL
TFPIR     TRUST FUND PAYMENT TO DEFENSE INDUSTRY RATE
TFPIRI    TRUST FUND PAYMENT TO DEFENSE INDUSTRY RATE-INPUT
USART     US APPROPRIATION RATE
USCPR     US CAPITAL PRODUCTION RATE
USDIL     US DEFENSE INDUSTRY LIQUIDITY
USDILI    US DEFENSE INDUSTRY LIQUIDITY-INITIAL LEVEL
USFA      US FORCE APPROPRIATION
USFAI     US FORCE APPROPRIATION-INITIAL LEVEL
USILDR    US DEFENSE INDUSTRY LIQUIDITY DEPLETION RATE
USPIR     US PAYMENT TO DEFENSE INDUSTRY RATE
```

Fig. 25. Equations, Subsector II-B

TABLE 2

RATES AND AUXILIARIES, SUBSECTOR II-B

Name and Type	Purpose	Line	Inputs	Purpose and Effect
USILDR, rate Eq. 2-10	Expends dollars in U.S. defense industry treasuries	1	DC	Percentage of liquidity expended as dividends, outside investments, etc. Determines expenditure rates for these purposes.
		2	LP & ILP	Calculates the expenditure rate for maintaining Congressional lobbies at the current level of effort.
		3	FPR	Calculates the expenditure rate producing weapon systems at the current rate; unit cost (FC) is given.
		4	CPR	Calculates the expenditure rate for building new production plant at the current rate; unit cost of capital (CP) is given.
		5		The four rates above are added to form USILDR.

Defense Industry Rate (USPIR), which depends in the production rate. The defense industries dispose of their liquidity through the U.S. Defense Industry Liquidity Depletion Rate (USILDR).

Subsector II-C

The flow diagram for this subsector is shown in Figure 26, and equations in Figure 27, and the explanation of complex rates and auxiliaries in Table 3. This subsector, composed entirely of auxiliaries and constants, represents the U.S. Government's decision-making process for defense equipment requests. The central auxiliary is U.S. Pressure on Congress for Force Appropriations (USPCFA), which determines request approval and denial rates (USFRAR and USFRDR) and the U.S. Appropriation Rate (USART). USPCFA is influenced by the major auxiliary U.S. Popular Support for Defense Appropriations (USPSFA), among others.

Subsector II-D

The flow diagram for this subsector is shown in Figure 28, and the equations in Figure 29. The U.S. Payment to Defense Industry Rate (USPIR) is simply the product of U.S. Completed Force Production (CFPUS) and weapon unit price (FP). The U.S. Appropriation Rate is based on the dollar value of U.S. Force Requests Processed (USFRP) modified by U.S. Pressure on Congress for Force Appropriations

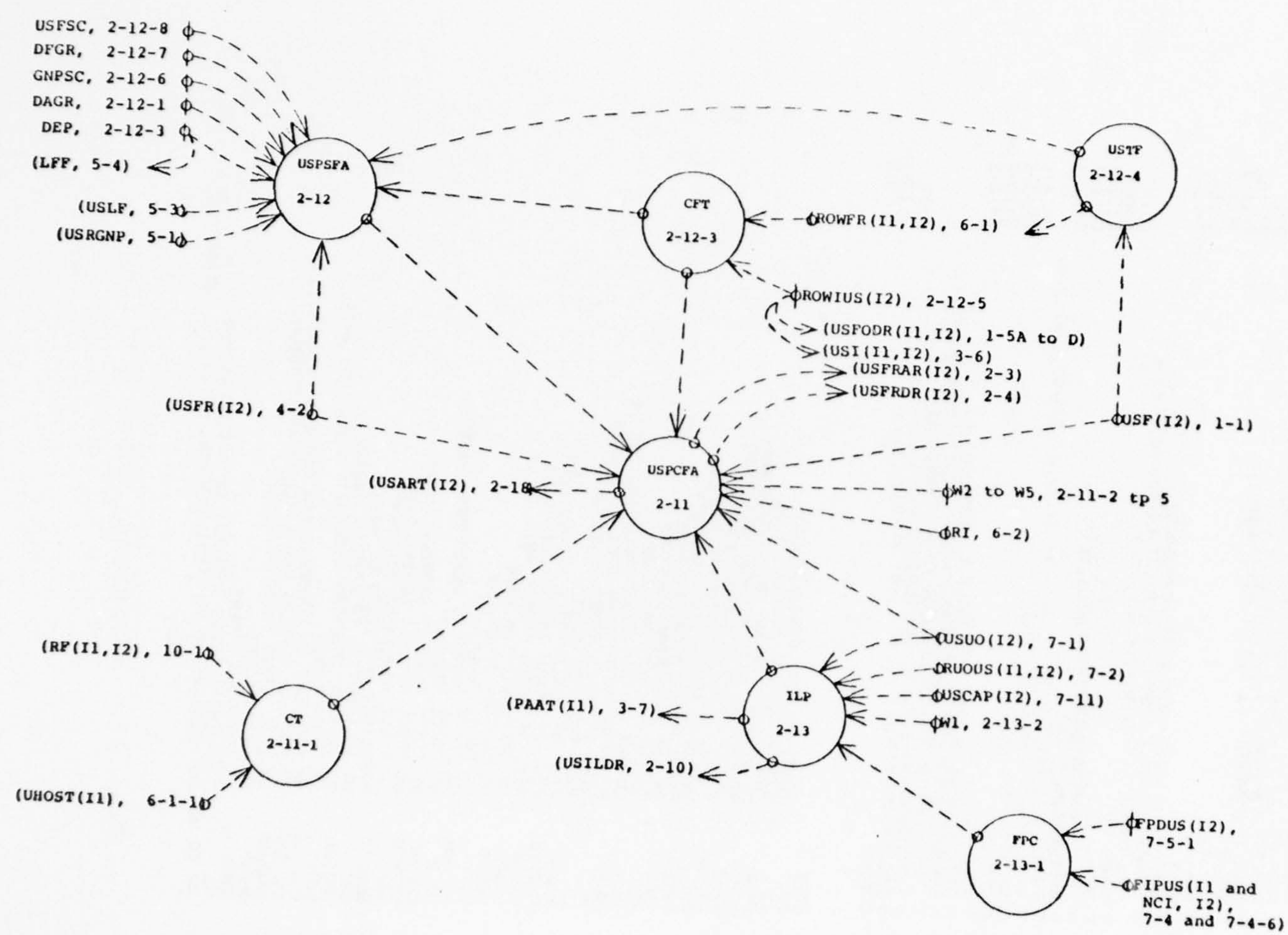

Fig. 26. Flow Diagram, Subsector II-C

```
NOTE
A USPCFA.K=(W2*SUM(CFT.K)/RI.K+W3*ILP.K+W4*USPSFA.K+
X W5*(SUM(CT.K)-SUM(USF.K)-SUM(USUO.K))/SUM(USFR.K))/
X (SUM(CFT.K)/RI.K+ILP.K+USPSFA.K+(SUM(CT.K)-
X SUM(USF.K)-SUM(USUO.K))/SUM(USFR.K))                      2-11
A CT.K(I1)=SUMV(RF.K(I1,*),1,4)*USHOST(I1)                  2-11-1
C W2=.2                                                     2-11-2
C W3=.6                                                     2-11-3
C W4=1.2                                                    2-11-4
C W5=2                                                      2-11-5
A USPSFA.K=(1+DEP-USLF.K)*(DAGR-USRGNP.K/
X SMOOTH(USRGNP.K,GNPSC))*(SUM(CFT.K)/SUM(USFR.K))*
X (DFGR-USTF.K/SMOOTH(USTF.K,USFSC))                        2-12
C DAGR=.03                                                  2-12-1
C DEP=.95                                                   2-12-2
A CFT.K(I1)=SUM(ROWFR.K)*ROWIUS(I1)                         2-12-3
A USTF.K=SUM(USF.K)                                         2-12-4
T ROWIUS=1/1/1/1/1/0/0/.4/.3/.3/0/.3/.2/.2/.2/0/0/.5/0/.3/0/
X 0/0/.2/.2/0/.4/.5/.3/.6/.2/0                              2-12-5
C GNPSC=3                                                   2-12-6
C DFGR=3                                                    2-12-7
C USFSC=2                                                   2-12-8
A ILP.K=((2-W1)*EXP(-(SUM(RUOUS.K)+SUM(USUO.K))/
X SUM(USCAP.K))+W1*(SUM(USCAP.K)-SUM(FPC.K))/SUM(USCAP.K))/
X (EXP(-(SUM(RUOUS.K)+SUM(USUO.K))/SUM(USCAP.K))+
X (SUM(USCAP.K)-SUM(FPC.K))/SUM(USCAP.K))                   2-13
A FPC.K=SUMV(FIPUS.K(*,I2),1,NCI)*FPDUS(I2)                 2-13-1
C W1=1                                                      2-13-2


NOTE
CFT        TOTAL COUNTRY FORCE REQUEST
CT         SINGLE COUNTRY THREAT TO US
DAGR       US DESIRED ANNUAL GNP GROWTH RATE
DEP        US DESIRED EMPLOYMENT PERCENTAGE
DFGR       US DESIRED FORCE GROWTH RATE
FIPUS      FORCES IN PRODUCTION BY THE US
FPC        US FORCE PRODUCTION CAPACITY
FPDUS      FORCE PRODUCTION DELAY-US
GNPSC      US GNP SMOOTHING CONSTANT
ILP        INDUSTRY LOBBY PRESSURE
NCI        NUMBER OF COUNTRIES INCLUDING THE US
PAAT       PRESSURE TO APPROVE ARMS TRANSFERS
RF         REST OF WORLD FORCE INVENTORY
RI         REGIONAL INSTABILITY
ROWFR      REST OF WORLD FORCE REQUESTED
ROWIUS     REST OF WORLD IMPORTANCE TO US
RUOUS      REST OF WORLD ORDERS HELD BY US
USART      US APPROPRIATION RATE
USCAP      US CAPITAL INVENTORY
USF        US FORCE INVENTORY
USFODR     US FORCE OVERSEAS DEPLOYMENT RATE
USFR       US FORCE REQUEST
USFRAR     US FORCE REQUEST APPROVAL RATE
USFRDR     US FORCE REQUEST DENIAL RATE
USFSC      US FORCE SMOOTHING CONSTANT
USHOST     PERCEIVED HOSTILITY BY US
USI        US INCLINATION TO APPROVE ORDERS
USILDR     US DEFENSE INDUSTRY LIQUIDITY DEPLETION RATE
USLF       US LABOR FORCE
USPCFA     US PRESSURE ON CONGRESS FOR FORCE APPROPRIATIONS
USPSFA     US POPULAR SUPPORT FOR FORCE APPROPRIATIONS
USRGNP     US REAL GROSS NATIONAL PRODUCT
USTF       US TOTAL FORCE
USUO       US UNFILLED ORDERS
W1         INDUSTRIAL LOBBY INTERNAL WEIGHTING FACTOR
W2 TO W5   US PRESSURE ON CONGRESS INTERNAL WEIGHTING FACTOR
```

Fig. 27. Equations, Subsector II-C

TABLE 3

RATES AND AUXILIARIES, SUBSECTOR II-C

Name and Type	Purpose	Line	Inputs	Purpose and Effect
USPCFA, aux. Eq. 2-11	Calculates the fraction of defense requests to be approved at any one time.	1	USPSFA	Expresses the popular support for defense expenditures as a percentage of requests (see below)
		2	ILP	Expresses the pressure on Congress of industrial lobbies (see below)
		3	CT	Calculates the direct threat to U.S. interests posed by all other countries (the public desires forces equal to all contingencies); equals Congress' assessment of total U.S. needs.
		4	USF, USUO	Forces in being and on order are subtracted from CT (line 3)
		5	USFR	The force increment required (CT - USF - USUO) is normalized by force requested (USFR).

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A DYNAMIC POLICY MODEL OF THE UNITED STATES ARMS TRANSFER PROCE--ETC(U)
SEP 79 D C CHIPMAN , J T CUNNINGHAM

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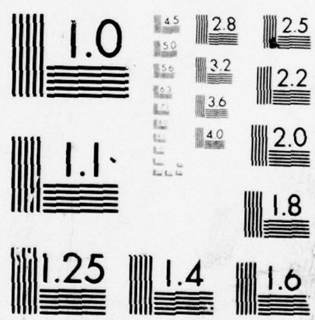

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

TABLE 3--Continued

Name and Type	Purpose	Line	Inputs	Purpose and Effect
		6	CFT	Calculates a country's incremental force request (ROWFR) multiplied by country's importance to U.S. (ROWIUS); creates corresponding desire to aid country with U.S. equipment.
		7	RI	Instability, calculated as sum of all incremental force requests (ROWFR); divided into CFT to normalize.
		8		Lines 1, 2, 5, and 7 are weighted by W2 through W5, which sum to 4.
USPSFA, aux. Eq. 2-12	See Line 1	9	DEP, USLF	The desired employment percentage (DEP) is compared to the actual employment percentage (USLF); low employment creates public demand for more defense expenditure.

TABLE 3--Continued

Name and Type	Purpose	Line	Inputs	Purpose and Effect
		10	DAGR, USRGNP, GNPSC	The desired annual growth rate (DAGR) in GNP is compared to the growth in GNP over GNPSC years; a shortfall causes public demand for more defense expenditure.
		11	CFT, USFR	CFT (line 6) is normalized by USFR (line 5).
		12	DFGR, USTF, USFSC	The desired growth rate (DFGR) is compared to the growth in forces over USFSC years; a shortfall causes public demand for more defense expenditure.
		13		Lines 9 through 12 are added.
ILP, aux. Eq. 2-13	See Line 2	14	USUO, RUOUS, USCAP	ILP is a weighted average (weight W1 ranges from zero to two) of total unfilled orders (USUO and RUOUS, normalized by

TABLE 3--Continued

Name and Type	Purpose	Line	Inputs	Purpose and Effect
				USCAP) and idle capacity (normalized by USCAP). The latter is a simple expression while the former is a negative exponential, reflecting greatly increasing industrial anxiety as unfilled orders approach zero.

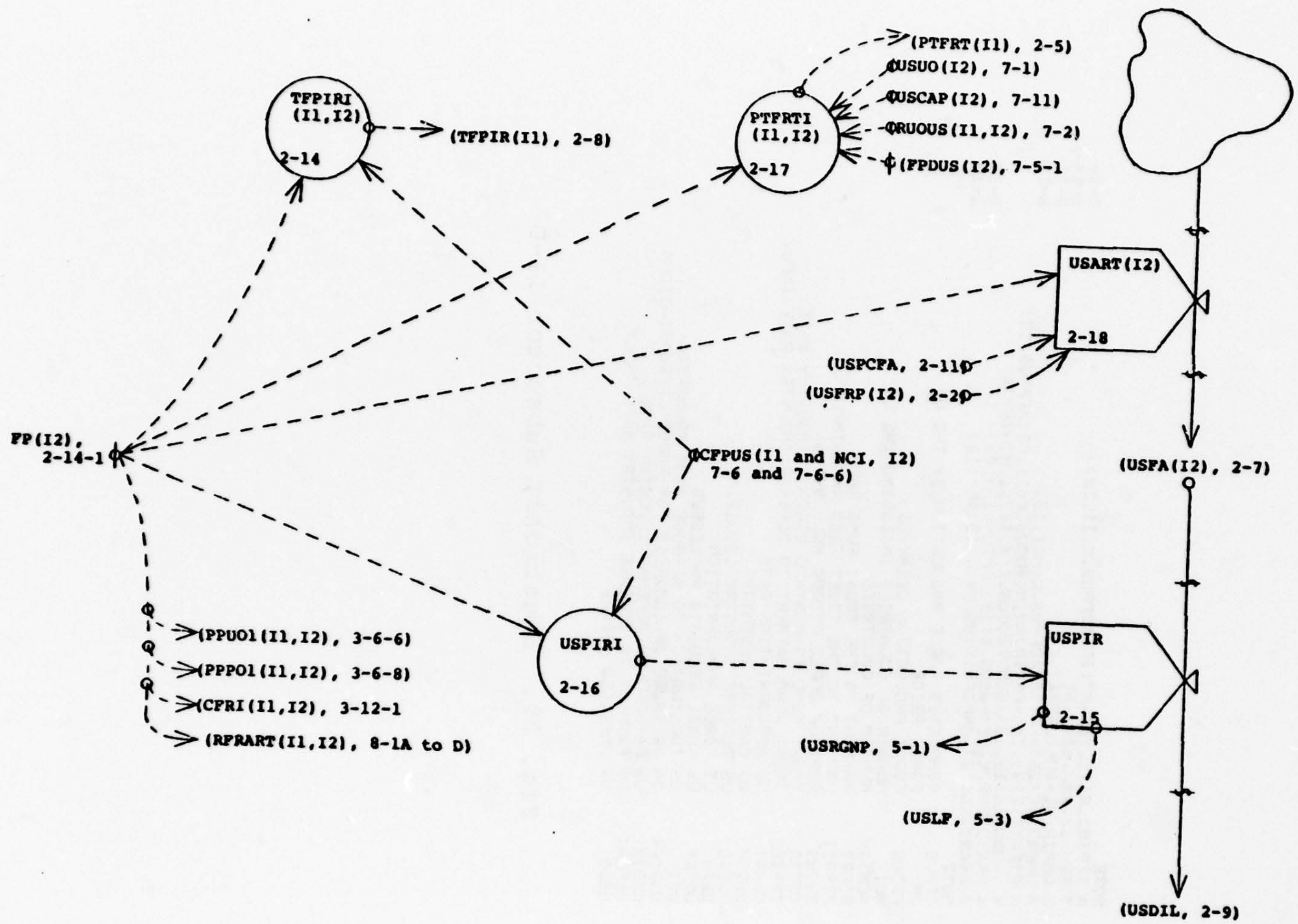

Fig. 28. Flow Diagram, Subsector II-D

```
NOTE
A TFPIRI.K(I1,I2)=FP(I2)*CFPUS.K(I1,I2)                              2-14
T FP=.1/.08/.034/.01                                                 2-14-1
R USPIR.KL=SUM(USPIRI.K)                                             2-15
A USPIRI.K(I2)=FP(I2)*CFPUS.K(NCI,I2)                                2-16
A PTFRTI.K(I1,I2)=FP(I2)*MIN(RUOUS.K(I1,I2)/FPDUS(I2)
X ,RUOUS.K(I1,I2)/SUMV(RUOUS.K(*,I2),1,NCNTRY)*
X MAX(USCAP.K(I2)-USUO.K(I2)/FPDUS(I2),0))                           2-17
R USART.KL(I2)=USPCFA.K*USFRP.K(I2)*FP(I2)                           2-18
NOTE
CFPUS     COMPLETED FORCE PRODUCTION BY THE US
FP        FORCE PRICE
FPDUS     FORCE PRODUCTION DELAY-US
NCI       NUMBER OF COUNTRIES INCLUDING THE US
NCNTRY    NUMBER OF COUNTRIES
PTFRT     PAYMENT TO THE TRUST FUND RATE
PTFRTI    PAYMENT TO THE TRUST FUND RATE-INPUT
RUOUS     REST OF WORLD ORDERS HELD BY US
TFPIR     TRUST FUND PAYMENT TO DEFENSE INDUSTRY RATE
TFPIRI    TRUST FUND PAYMENT TO DEFENSE INDUSTRY RATE-INPUT
USART     US APPROPRIATION RATE
USCAP     US CAPITAL INVENTRY
USDIL     US DEFENSE INDUSTRY LIQUIDITY
USFA      US FORCE APPROPRIATION
USFRP     US FORCE REQUESTS PROCESSED
USI       US INCLINATION TO APPROVE ARMS TRANSFERS
USPCFA    US PRESSURE ON CONGRESS FOR FORCE APPROPRIATIONS
USPIR     US PAYMENT TO DEFENSE INDUSTRY RATE
USPIRI    US PAYMENT TO DEFENSE INDUSTRY RATE-INPUT
USUO      US UNFILLED ORDERS
```

Fig. 29. Equations, Subsector II-D

(USPCFA). The two auxiliaries Trust Fund Payment to Defense Industry Rate-Input (TFPIRI) and Payment to Trust Fund Rate-Input (PTFRTI) aggregate information on production and planned production rates, respectively, and pass this information to Trust Fund Payment to Defense Industry Rate (TFPIR) and Payment to Trust Fund Rate (PTFRT).

Subsector III-A

The flow diagram for this subsector is shown in Figure 30, and equations in Figure 31, and the explanation of complex rates and auxiliaries in Table 4. Rest of World Orders received by the U.S. (RORUS) are processed through an approval delay (ROPR) into the level of processed orders (ROPUS). Processed orders are immediately divided by the U.S. Inclination to Approve Orders (USI) into approved orders, which become unfilled orders for U.S. production (RUOUS), and disapproved orders, which become unfilled orders for ROW production (RUOR). The assumption necessary is that some producing country will be willing to sell the arms requested. The approval rate (ROARUS) and denial rate (RODRUS) are both functions of the level of processed orders (ROPUS) and U.S. Inclination to Approve Orders (USI).

Subsector III-B

The flow diagram for this subsector is shown in Figure 32, and the equations in Figure 33. This subsector monitors the arms transfer ceiling and insures that it is

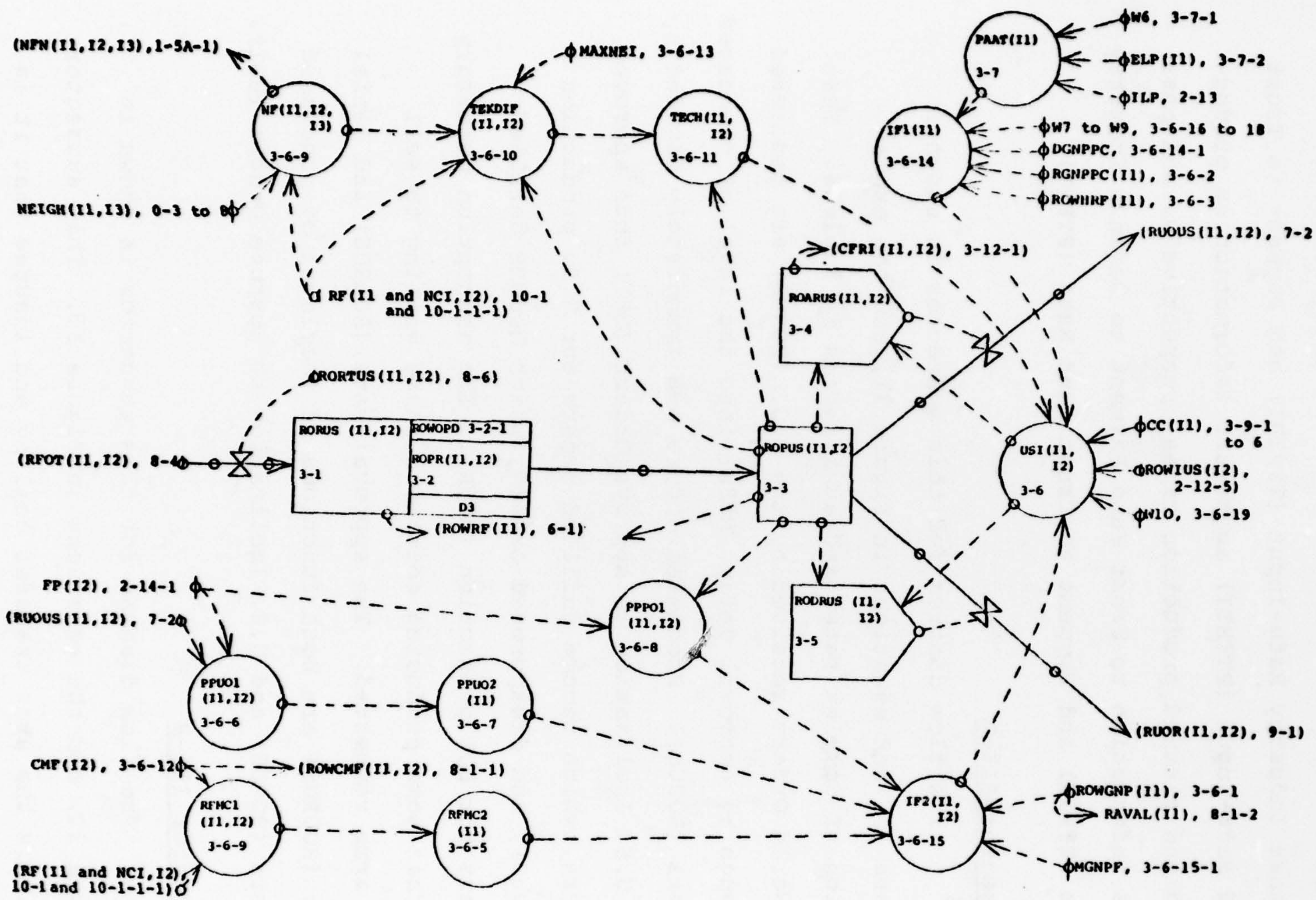

Fig. 30. Flow Diagram, Subsector III-A

```
NOTE
L RORUS.K(I1,I2)=RORUS.J(I1,I2)+DT*(RORTUS.JK(I1,I2)-
X ROPR.JK(I1,I2))                                              3-1
N RORUS(I1,I2)=RORUSI(I1,I2)                                   3-1-1
T RORUSI(*,1)=0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/
X 0/0/0/0/0/0/0/0/0/0/0/0                                      3-1-2
T RORUSI(*,2)=0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/
X 0/0/0/0/0/0/0/0/0/0/0/0                                      3-1-3
T RORUSI(*,3)=0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/
X 0/0/0/0/0/0/0/0/0/0/0/0                                      3-1-4
T RORUSI(*,4)=0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/
X 0/0/0/0/0/0/0/0/0/0/0/0                                      3-1-5
R ROPR.KL(I1,I2)=DELAY3(RORTUS.JK(I1,I2),ROWOPD)               3-2
C ROWOPD=.5                                                    3-2-1
L ROPUS.K(I1,I2)=ROPUS.J(I1,I2)+DT*(ROPR.JK(I1,I2)-
X ROARUS.JK(I1,I2)-RODRUS.JK(I1,I2))                           3-3
N ROPUS(I1,I2)=ROPUSI(I1,I2)                                   3-3-1
T ROPUSI(*,1)=0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/
X 0/0/0/0/0/0/0/0/0/0/0/0                                      3-3-2
T ROPUSI(*,2)=0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/
X 0/0/0/0/0/0/0/0/0/0/0/0                                      3-3-3
T ROPUSI(*,3)=0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/
X 0/0/0/0/0/0/0/0/0/0/0/0                                      3-3-4
T ROPUSI(*,4)=0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/
X 0/0/0/0/0/0/0/0/0/0/0/0                                      3-3-5
R ROARUS.KL(I1,I2)=ROPUS.K(I1,I2)*USI.K(I1,I2)                 3-4
R RODRUS.KL(I1,I2)=ROPUS.K(I1,I2)*(1-USI.K(I1,I2))             3-5
A USI.K(I1,I2)=(U10*ROWIUS(I1)+(2-U10)*IF1.K(I1)*
X IF2.K(I1,I2)*CC(I1)*TECH.K(I1,I2))/(ROWIUS(I1)+
X IF1.K(I1)*IF2.K(I1,I2)*CC(I1)*TECH.K(I1,I2))                 3-6
T ROWGNP=13770/178/311/4069/716/9991/2497/170/129/121/46/101/
X 37/9/30/261/50/300/51/24/25/24/5/109/79/37/101/570/691/75/
X 189/0                                                        3-6-1
T RGNPPC=4397/1961/743/3634/3805/2327/356/461/766/331/54/635/
X 405/252/465/750/537/1016/210/210/178/79/137/1089/206/525/
X 2786/524/107/1404/913/0                                      3-6-2
T ROWHRF=1/.8/.8/.9/1/.1/.15/.3/.4/.4/0/.4/.3/.4/.6/.6/.2/.3/
X .3/.2/.3/0/.1/.1/.4/.4/.8/.3/.8/.2/.3/0                      3-6-3
A RFMC1.K(I1,I2)=RF.K(I1,I2)*CMF(I2)                           3-6-4
A RFMC2.K(I1)=SUMV(RFMC1.K(I1,*),1,4)                          3-6-5
A PPUO1.K(I1,I2)=RUOUS.K(I1,I2)*FP(I2)                         3-6-6
A PPUO2.K(I1)=SUMV(PPUO1.K(I1,*),1,4)                          3-6-7
A PPPO1.K(I1,I2)=ROPUS.K(I1,I2)*FP(I2)                         3-6-8
A NF.K(I1,I2,I3)=FIND1(RF.K(I1,I2),NEIGH(I1,I3),I1,I2,I3,
X NCI)                                                         3-6-9
A TEKDIF.K(I1,I2)=ROPUS.K(I1,I2)-RF.K(I1,I2)-
X SUMV(NF(I1,I2,*),1,MAXNEI)                                   3-6-10
A TECH.K(I1,I2)=CLIP(0,1,TEKDIF.K(I1,I2),ROPUS.K(I1,I2))       3-6-11
T CMF=.0004/.0181/.0041/.0012                                  3-6-12
C MAXNEI=6                                                     3-6-13
A IF1.K(I1)=(U7*PAAT.K(I1)+U8*ROWHRF(I1)+U9*RGNPPC(I1)/
X DGNPPC)/(PAAT.K(I1)+ROWHRF(I1)+RGNPPC(I1)/DGNPPC)            3-6-14
C DGNPPC=80                                                    3-6-14-1
A IF2.K(I1,I2)=1.5-(RFMC2.K(I1)+PPUO2.K(I1)+PPPO1.K(I1,I2))/
X (MGNPF*ROWGNP(I1))                                           3-6-15
C MGNPF=.0038                                                  3-6-15-1
C U7=1.5                                                       3-6-16
C U8=.75                                                       3-6-17
```

Fig. 31. Equations, Subsector III-A

```
C W9=.75                                                       3-6-18
C W10=1.5                                                      3-6-19
A PAAT.K(I1)=(W6*ELP(I1)+(2-W6)*ILP.K)/(ELP(I1)+ILP.K)         3-7
C W6=1                                                         3-7-1
T ELP=0/.4/.3/0/0/0/0/.1/.1/0/0/0/0/0/0/0/0/0/0/0/0/
X 0/0/0/0/1/0/0/0/0/0                                          3-7-2
NOTE
CC          CEILING COMPARATOR
CFR         CEILING FILL RATE
CMF         UNIT COST OF MAINTAINING FORCE
DGNPPC      DESIRED GROSS NATIONAL PRODUCT PER CAPITA
ELP         ETHNIC LOBBY PRESSURE
FP          FORCE PRICE
IF1 & IF2   USI-INTERMEDIATE FACTORS
ILP         INDUSTRY LOBBY PRESSURE
MAXNEI      MAXIMUM NUMBER OF NEIGHBORING COUNTRIES
MGNPF       MILITARY GROSS NATIONAL PRODUCT FACTOR
NEIGH       NEIGHBOR INDICATOR
NF          NEIGHBORING COUNTRY FORCE
PAAT        PRESSURE TO APPROVE ARMS TRANSFERS
PPPO1       PURCHASE PRICE OF PROCESSED ORDERS FACTOR
PPUO1 & 2   PURCHASE PRICE OF UNFILLED ORDERS FACTORS
RF          REST OF WORLD FORCE INVENTORY
RFMC1 & 2   REST OF WORLD FORCE MAINTENANCE COST FACTORS
RFOT        REST OF WORLD FOREIGN ORDERS TOTAL
RFRART      REST OF WORLD FORCE REQUEST APPROVAL RATE
RGNPPC      REST OF WORLD GROSS NATIONAL PRODUCT PER CAPITA
ROARUS      REST OF WORLD ORDERS TO US - APPROVAL RATE
RODRUS      REST OF WORLD ORDERS TO US - DENIAL RATE
ROPR        REST OF WORLD ORDERS TO US - PROCESSING RATE
ROPUS       REST OF WORLD ORDERS TO US - PROCESSED
ROPUSI      REST OF WORLD ORDERS TO US - PROCESSED - INITIAL LEVEL
RORTUS      REST OF WORLD ORDERING RATE TO US
RORUS       REST OF WORLD ORDERS RECEIVED BY US
RORUSI      REST OF WORLD ORDERS RECEIVED BY US - INITIAL LEVEL
ROWFR       REST OF WORLD FORCE REQUESTED
ROWGNP      REST OF WORLD GROSS NATIONAL PRODUCT
ROWHRF      REST OF WORLD HUMAN RIGHTS FACTOR
ROWIUS      REST OF WORLD IMPORTANCE TO US
ROWOPD      REST OF WORLD ORDERS TO US - PROCESSING DELAY
RUOR        REST OF WORLD UNFILLED ORDERS HELD BY REST OF WORLD
RUOUS       REST OF WORLD UNFILLED ORDERS HELD BY US
TECH        USI TECHNOLOGICAL FACTOR
TEKDIF      FORCE DIFFERENCE FOR A GIVEN TECHNOLOGY LEVEL
USI         US INCLINATION TO APPROVE ORDERS
W6          PAAT INTERNAL WEIGHTING FACTOR
W7 TO W10   USI INTERNAL WEIGHTING FACTORS
```

Fig. 31--Continued

TABLE 4

RATES AND AUXILIARIES, SUBSECTOR III-A

Name and Type	Purpose	Line	Inputs	Purpose and Effect
USI, aux. Eq. 3-6	Expresses approval rate of processed requests as a percentage of same; represents the entire U.S. Government arms transfer decision making process.	1	ROWIUS	Country's importance to the U.S. plays a major, if not overriding, role in arms transfer decisions, according to several officials interviewed by the authors.
		2	IF2	An intermediate factor representing a country's ability to buy the proposed order without damaging its economy (see below).
		3	IF1	An intermediate factor composed of three other factors in arms transfer decisions (see below).
		4	CC	A "gate" (whose value is either zero or one) from the arms transfer ceiling accounting machinery (Sector III-B).

TABLE 4--Continued

Name and Type	Purpose	Line	Inputs	Purpose and Effect
		5	TECH	A zero-or-one auxiliary which insures that no country may purchase weapons of a technological category higher than it or its neighbors possesses.
		6		Lines 2 through 5 are multiplied together and weighted by W10 with Line 1; W10 may vary from zero to two.
IF2, aux. Eq. 3-6-15	See Line 2	7	RFMC2	Country's cost of maintaining current forces; unit cost of maintaining force (CMF) given.
		8	PPUO2	Country's cost of purchasing U.S. production currently on order; unit prices (FP) are given.
		9	PPPO1	Country's cost of purchasing the proposed order; unit prices (FP) are given.

TABLE 4--Continued

Name and Type	Purpose	Line	Inputs	Purpose and Effect
		10		Lines 7 through 9 are summed and compared to the maximum fraction (MGNPF) of the country's GNP (ROWGNP) the U.S. considers appropriate for defense expenditure.
IF1, aux. Eq. 3-6-14	See Line 3	11	PAAT	Weighted average (weight W6 can vary between zero and two) of ethnic lobby pressure (ELP) and industrial lobby pressure (ILP).
		12	ROWHRF	ROW Human Rights Factor, on a scale of zero to one.
		13	RGNPPC, DGNPPC	Country's GNP Per Capita is compared to the U.S. desired GNP Per Capita for other countries (DGNPPC). A standard of living (RGNPPC) lower than desired (DGNPPC) make approval less likely.

TABLE 4--Continued

Name and Type	Purpose	Line	Inputs	Purpose and Effect
		14		To give appropriate emphasis to each factor, lines 11 through 13 are weighted by W7 through W9, which total to 3.

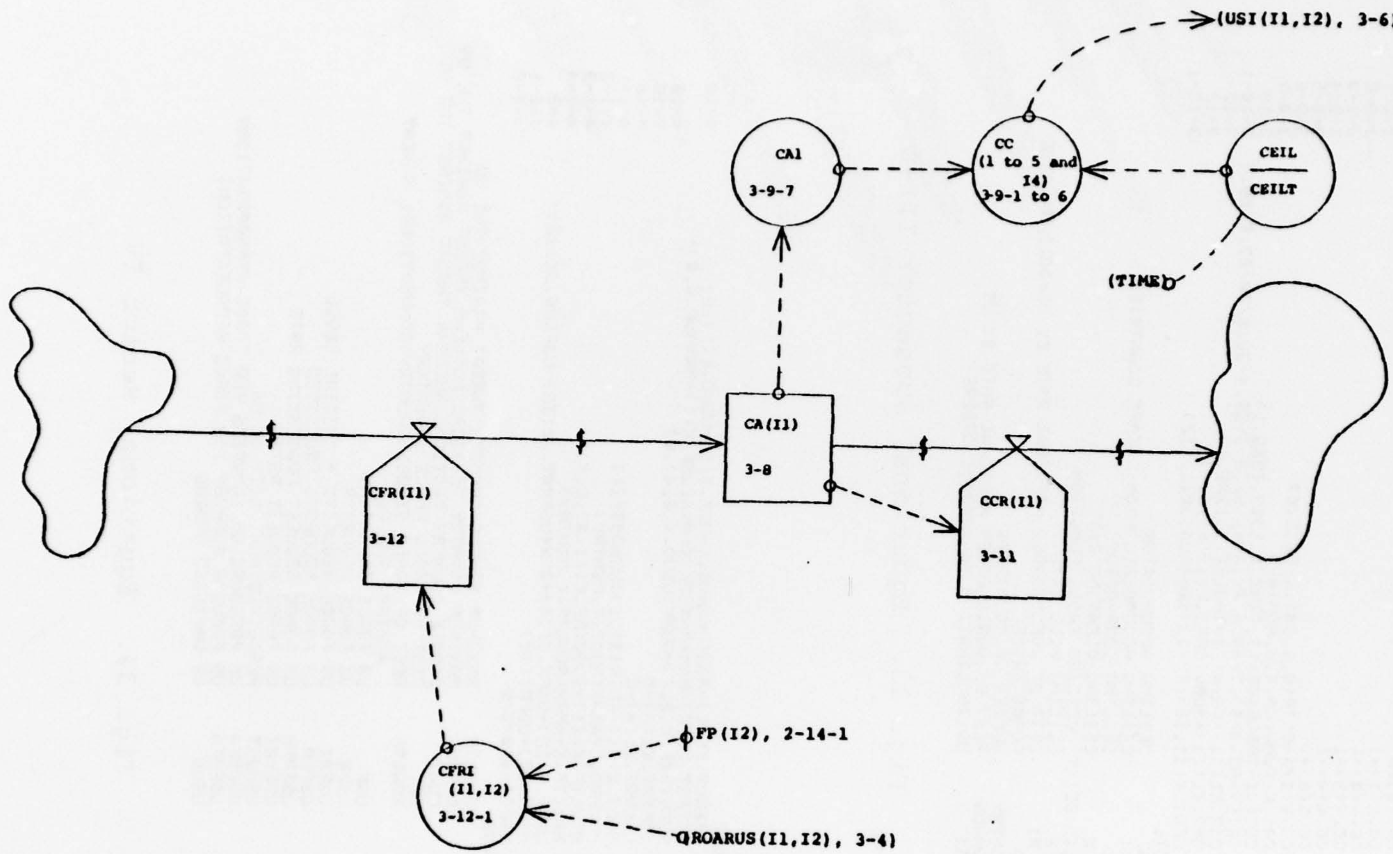

Fig. 32. Flow Diagram, Subsector III-B

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NOTE
L CA.K(I1)=CA.J(I1)+DT*(CFR.JK(I1)-CCR.JK(I1))                      3-8
N CA(I1)=0                                                          3-8-1
A CC.K(1)=1                                                         3-9-1
A CC.K(2)=1                                                         3-9-2
A CC.K(3)=1                                                         3-9-3
A CC.K(4)=1                                                         3-9-4
A CC.K(5)=1                                                         3-9-5
A CC.K(I4)=CLIP(0,1,CA1.K,CEIL.K)                                   3-9-6
A CA1.K=SUMV(CA.K,6,NCNTRY)                                         3-9-7
A CEIL.K=TABLE(CEILT,TIME.K,1979,1989,1)                            3-10
T CEILT=58.4/53.7/49.4/45.5/41.8/38.5/35.4/32.6/30/27.6/25.4        3-10-1
R CCR.KL(I1)=CA.K(I1)*PULSE(1,1980,1)                               3-11
R CFR.KL(I1)=SUMV(CFR1.K(I1,*),1,4)                                 3-12
A CFR1.K(I1,I2)=FP(I2)*ROARUS.JK(I1,I2)                             3-12-1
NOTE
CA          CEILING ACCUMULATOR
CA1         CEILING ACCUMULATOR-NON EXEMPT COUNTRIES
CC          CEILING COMPARATOR
CCR         CEILING CLEARING RATE
CEIL/CEILT   CEILING TABLE FUNCTION
CFR         CEILING FILL RATE
CFR1        REST OF WORLD ORDER APPROVAL RATE BY US-DOLLAR VALUE
FP          FORCE PRICE
NCNTRY      NUMBER OF COUNTRIES
ROARUS      REST OF WORLD ORDER APPROVAL RATE BY US
USI         US INCLINATION TO APPROVE ORDERS
```

Fig. 33. Equations, Subsector III-B

```
NOTE
R USFRRT.KL(1)=MAX(MAXNUC.K-USF.K(1)-USUO.K(1),0)                   4-1A
R USFRRT.KL(2)=MAX(MAXLTF.K-MAX(USF.K(1)-MAXNUC.K,0)-
X SUMV(USF.K,2,4)-SUMV(USUO.K,2,4),0)                               4-1B
R USFRRT.KL(3)=0                                                    4-1C
R USFRRT.KL(4)=0                                                    4-1D
A NUCT.K(I1)=RF.K(I1,1)*USHOST(I1)                                  4-1-1
A MAXNUC.K=AMAX(NUCT.K,NCNTRY)                                      4-1-2
A ROWLTF.K(I1)=SUMV(RF.K(I1,*),2,4)                                 4-1-3
A MAXLTF.K=AMAX(ROWLTF.K,NCNTRY)                                    4-1-4
L USFR.K(I2)=USFR.J(I2)+DT*(USFRRT.JK(I2)-USFRPR.JK(I2))            4-2
N USFR(I2)=USFRI(I2)                                                4-2-1
T USFRI=0/0/0/0                                                     4-2-2
NOTE
     MAXLTF     MAXIMUM SINGLE COUNTRY THREAT AGAINST THE US
     MAXNUC     MAXIMUM COUNTRY TACTICAL NUCLEAR THREAT AGAINST THE US
     NUCT       SINGLE COUNTRY TACTICAL NUCLEAR THREAT AGAINST THE US
     RF         REST OF WORLD FORCE INVENTORY
     ROWLTF     REST OF WORLD SINGLE COUNTRY CONVENTIONAL THREAT
                  AGAINST THE US
     USF        US FORCE INVENTORY
     USFR       US FORCE REQUESTS
     USFRI      US FORCE REQUESTS - INITIAL LEVEL
     USFRP      US FORCE REQUESTS PROCESSED
     USFRPR     US FORCE REQUEST PROCESSING RATE
     USFRRT     US FORCE REQUEST RATE
     USHOST     PERCEIVED HOSTILITY OF US
     USPCFA     US PRESSURE ON CONGRESS FOR FORCE APPROPRIATIONS
     USPSFA     US POPULAR SUPPORT FOR FORCE APPROPRIATIONS
     USUO       US UNFILLED ORDERS
```

Fig. 34. Equations, Sector IV

not exceeded during a given year. The Ceiling Accumulator (CA) begins at zero each year and accumulates the dollar amounts of all approved sales from year's beginning. The Ceiling Comparator (CC) compares this accumulation plus the value of a proposed order with the current ceiling from a table function (CEILT). If approval of the proposed sale would cause the ceiling to be exceeded, the comparator becomes zero and approval is blocked; otherwise, the comparator is one, and the sale is not blocked by the ceiling. The ceiling applies only to nonallied countries. At the end of each year, a pulse function causes the Ceiling Clearing Rate (CCR) to empty the Ceiling Accumulator.

Sector IV

The flow diagram for this sector is shown in Figure 35, and the equations in Figure 34. In this sector, the U.S. Force Request Rate (USFRRT) represent the Executive Branch's requirements determination process and meters requests into the level U.S. Force Requested (USFR). The request rate for tactical nuclear weapons equals the excess, if any, of the maximum tactical nuclear threat (MAXNUC) to United State's interests by any one country over the current U.S. tactical nuclear inventory plus weapons on order. The request rate for state-of-the-art equipment equals the excess, if any, of the maximum conventional threat (MAXLTF) to U.S. interests by any one country over the current U.S. conventional

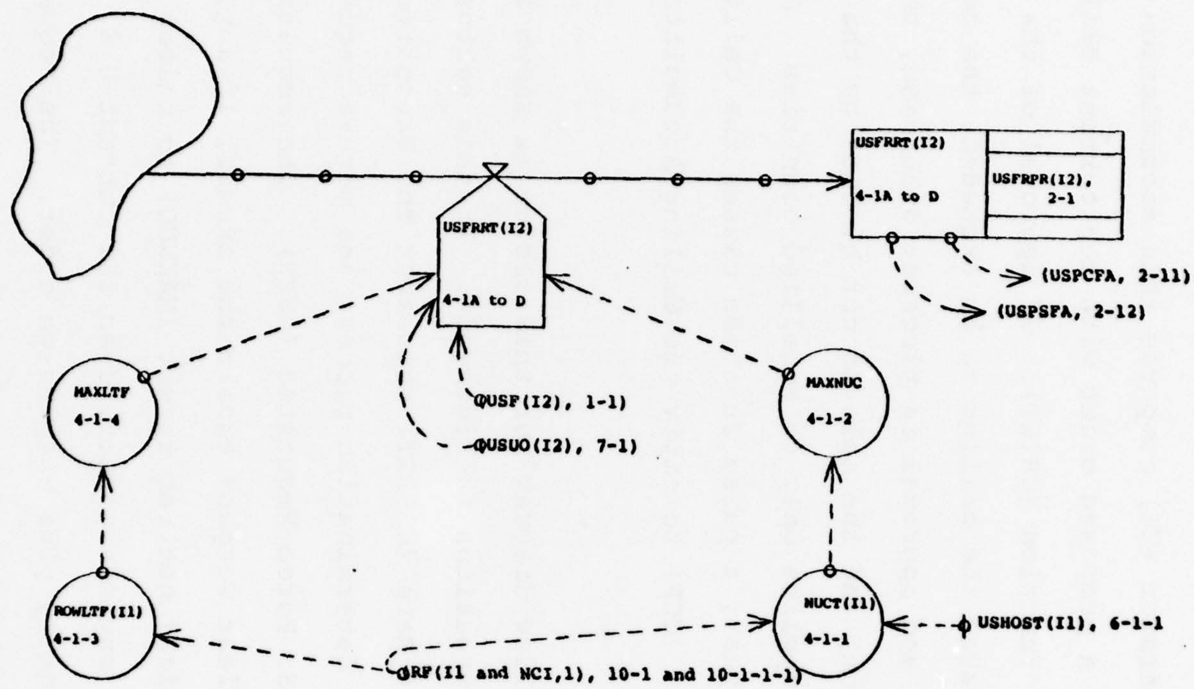


Fig. 35. Flow Diagram, Sector IV

force inventory, after allowances for equipment on order and any U.S.-owned excess tactical nuclear weapons. Request rates for modern and dated equipment are assumed to be zero.

Sector V

The flow diagram for this sector is shown in Figure 36, and the equations in Figure 37. This sector simulates the U.S. economy from a macro or high resolution perspective. A function of U.S. GNP with time (GNPF) has been represented by the Schumpeter three-cycle schema (17:109) superimposed on a growth curve. The output of this function combines with payments to the defense industry to produce U.S. Real GNP (USRGNP). The GNP function (GNPF) also drives a Labor Force Function (LFF), which uses Okun's Law (17:160) to calculate the percentage employed. The U.S. Percentage Employed (USLF) is then calculated using the Labor Force Function, and the payments to defense industry multiplied by an Employment Constant (EC). Lastly, the Effect on the U.S. Balance of Trade (EUSBT) is computed by subtracting the Cost of Maintaining U.S. Forces Overseas (CMFO) from the Trust Fund Payment to Defense Industry Rate (TFPIR).

Sector VI

The flow diagram for this sector is shown in Figure 39, and the equations in Figure 38. This sector calculates a country's incremental force request (ROWFR)

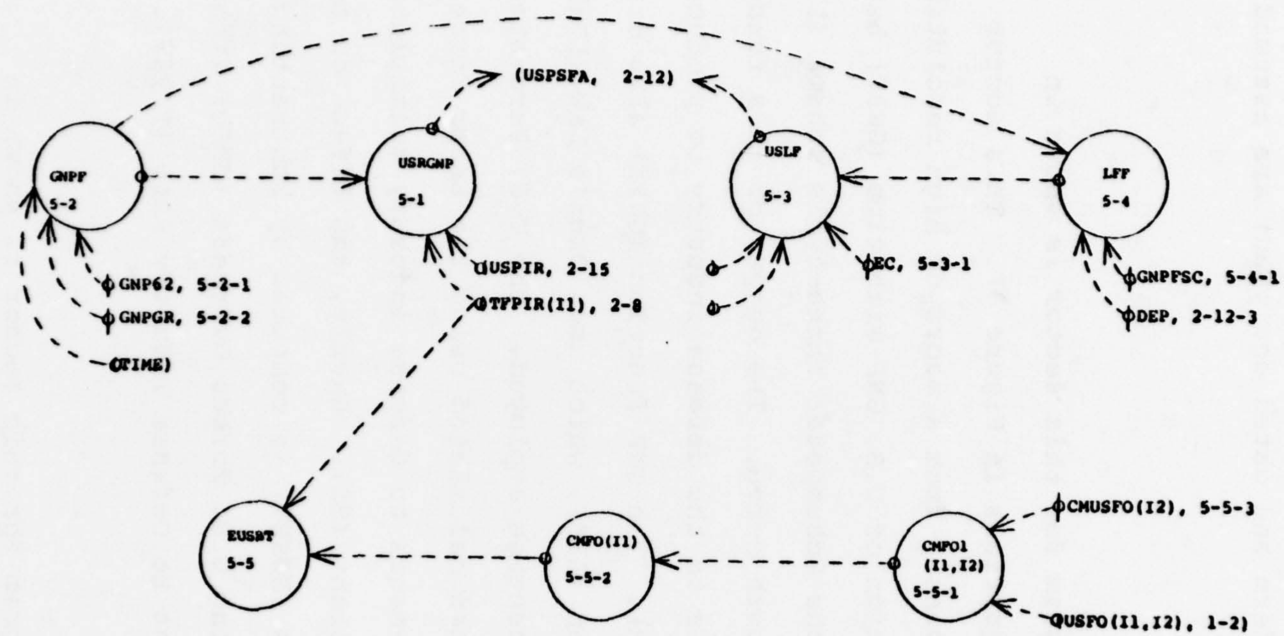


Fig. 36. Flow Diagram, Sector V

```
NOTE
A USRGNP.K=GNPF.K+USPIR.K+SUM(TFPIR.JK)                          5-1
A GNPF.K=GNP62*EXP((TIME.K-1962)*LOGN(1+GNPGR))*(1+.15*SIN(6.28*
X (TIME.K-1962)/60)+.025*SIN(6.28*(TIME.K-1962)/10)+
X .025*SIN(6.28*(TIME.K-1962)/3.33))                             5-2
C GNP62=8000                                                     5-2-1
C GNPGR=.032                                                     5-2-2
A USLF.K=LFF.K+(USPIR.JK+SUM(TFPIR.JK))*EC                       5-3
C EC=.000049                                                     5-3-1
A LFF.K=DEP-(SMOOTH(GNPF.K,GNPFSC)-GNPF.K)/(3.2*GNPF.K)          5-4
C GNPFSC=5                                                       5-4-1
S EUSBT.K=SUM(TFPIR.JK)-SUM(CMFO.K)                              5-5
A CMFO1.K(I1,I2)=CMUSFO(I2)*USFO.K(I1,I2)                        5-5-1
A CMFO.K(I1)=SUMV(CMFO1.K(I1,*),1,4)                             5-5-2
T CMUSFO=.0004/.0181/.0041/.0012                                 5-5-3
NOTE
CMFO       COST OF MAINTAINING US FORCES OVERSEAS BY COUNTRY
CMFO1      COST OF MAINTAINING US FORCES OVERSEAS BY
           SYSTEM AND COUNTRY
CMUSFO     COST OF MAINTAINING US FORCES OVERSEAS
DEP        DESIRED EMPLOYMENT PERCENTAGE
EC         EMPLOYMENT CONSTANT
EUSBT      EFFECT ON US BALANCE OF TRADE
GNP62      1962 US REAL GROSS NATIONAL PRODUCT IN 1972 DOLLARS
GNPF       US GROSS NATIONAL PRODUCT FUNCTION
GNPFSC     GNPF SMOOTHING FUNCTION
GNPGR      GROSS NATIONAL PRODUCT GROWTH RATE
LFF        US LABOR FORCE FUNCTION
TFPIR      TRUST FUND PAYMENT TO DEFENSE INDUSTRY RATE
USFO       US FORCE OVERSEAS
USLF       US LABOR FORCE
USPIR      US PAYMENTS TO DEFENSE INDUSTRY RATE
USRGNP     US REAL GROSS NATIONAL PRODUCT(CONSTANT DOLLARS)
```

Fig. 37. Equations, Sector V

```
NOTE
A ROWFR.K(I1)=AMAXX(RFRI.K(I1,*),NCNTRY,I1)+USTF.K*
X USHOST(I1)-ROWTF.K(I1)-SUMV(RFRA.K(I1,*),1,4)-
X SUMV(RFOT.K(I1,*),1,4)-SUMV(RORUS.K(I1,*),1,4)
X -SUMV(ROPUS.K(I1,*),1,4)-SUMV(RUOUS.K(I1,*),1,4)-
X SUMV(RUOR.K(I1,*),1,4)-SUMV(USFO.K(I1,*),1,4)+
X AMAXX(RFRIR.K(I1,*),NCNTRY,I1)                                 6-1
T USHOST=0/0/0/0/0/1/.5/0/.2/0/1/0/0/0/0/.1/.5/.6/0/0/0/0/0/
X .5/0/0/.1/.3/0/.3/.5/0                                         6-1-1
A ROWTF.K(I1)=SUMV(RF.K(I1,*),1,4)                               6-1-2
A ROWTF.K(NCI)=USTF.K                                            6-1-2-1
A RFRI.K(I1,I3)=FIND3(RHOST(I1,*),NEIGH(I1,*),ROWTF.K,
X I1,I3,NCI)                                                     6-1-3
A RFRIR.K(I1,I3)=RHOST(I1,I3)*FIND2(ROWTF.K,NEIGH(I1,I3),I1,I3,
X NCI)                                                           6-1-4
A RI.K=SUM(ROWFR.K)                                              6-2
NOTE
     NEIGH      NEIGHBOR INDICATOR
     RF         REST OF WORLD FORCE INVENTORY
     RFOT       REST OF WORLD FOREIGN ORDERS TOTAL
     RFRA       REST OF WORLD FORCE REQUESTS APPROVED
     RFRART     REST OF WORLD FORCE REQUEST APPROVAL RATE
     RFRI       REST OF WORLD FORCE REQUESTED-INPUT
     RFRIR      REST OF WORLD OFFENSIVE FORCE REQUIRED-INPUT
     RHOST      PERCEIVED REST OF WORLD HOSTILITY TO REST OF WORLD
     RI         REGIONAL INSTABILITY
     ROPUS      REST OF WORLD ORDERS TO US PROCESSED
     RORUS      REST OF WORLD UNFILLED ORDERS HELD BY US
     ROWFR      REST OF WORLD FORCE REQUESTED
     ROWTF      REST OF WORLD TOTAL FORCE BY COUNTRY
     RUOR       REST OF WORLD UNFILLED ORDERS HELD BY REST OF WORLD
     RUOUS      REST OF WORLD UNFILLED ORDERS HELD BY US
     USFO       US FORCES OVERSEAS
     USFODR     US FORCE OVERSEAS DEPLOYMENT RATE
     USHOST     PERCEIVED US HOSTILITY TO REST OF WORLD
     USI        US INCLINATION TO APPROVE ORDERS
     USPCFA     US PRESSURE ON CONGRESS FOR FORCE APPROPRIATIONS
     USPSFA     US POPULAR SUPPORT FOR FORCE APPROPRIATIONS
     USTF       US TOTAL FORCE
```

Fig. 38. Equations, Sector VI

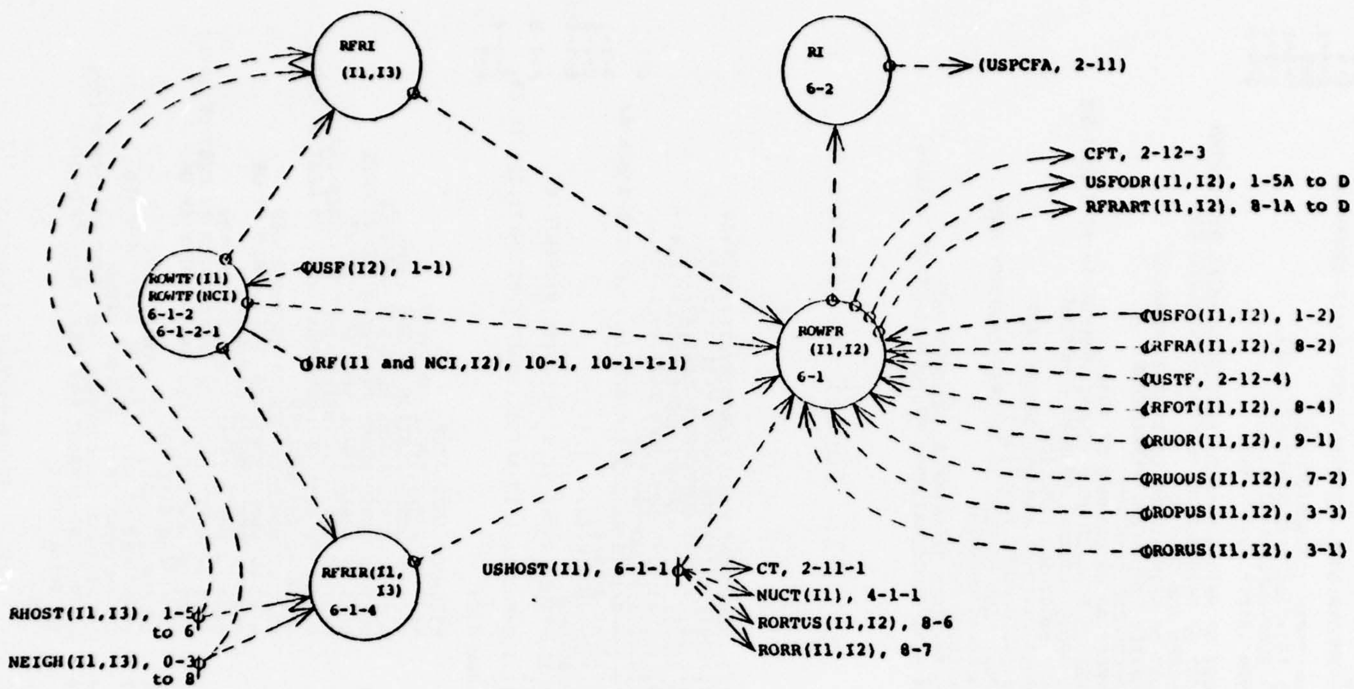


Fig. 39. Flow Diagram, Sector VI

without regard to technology levels. The incremental request equals the largest threat from a neighboring country (RFRI) plus perceived threat from the U.S. plus force desired for offensive purposes (RFRIR), less any force requests and orders in process, less U.S. forces deployed in-country (USFO). A country's incremental force request is combined with fiscal constraints in Sector VIII to produce orders for specific quantities of specific weapons by technology level.

Subsector VII-A

The flow diagram for this subsector is shown in Figure 40, and the equations in Figure 41. This subsector portrays all unfilled orders held by the U.S. defense industry. Orders made by the U.S. (USUO) are filled as completed production is deployed by the Force Deployment Rate by the U.S. (FDRTUS). Orders made by other countries (RUOUS) are filled as completed production is deployed by the Force Deployment Rate by ROW (FDRR).

Subsector VII-B

The flow diagram for this subsector is shown in Figure 42, the equations in Figure 43, and the explanation of complex rates and auxiliaries in Table 5. The U.S. defense industry is portrayed in this sector. The Planned Force Production Rate (PFPRUS) enters raw materials into production; work-in-process is contained in the level

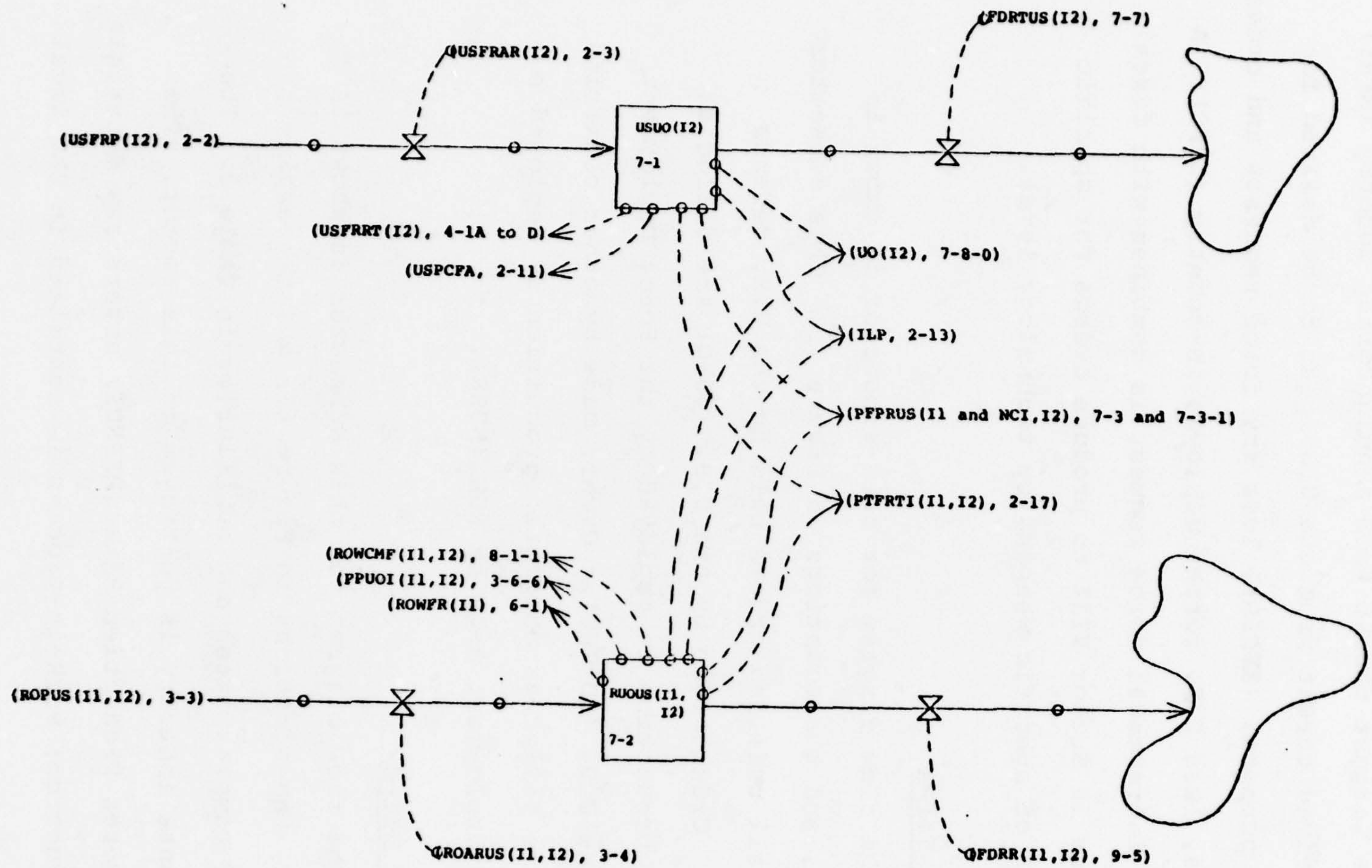


Fig. 40. Flow Diagram, Subsector VII-A

```
NOTE
L USUO.K(I2)=USUO.J(I2)+DT*(USFRAR.JK(I2)-FDRTUS.JK(I2))          7-1
N USUO(I2)=USUOI(I2)                                               7-1-1
T USUOI=0/0/0/0                                                    7-1-2
L RUOUS.K(I1,I2)=RUOUS.J(I1,I2)+DT*(ROARUS.JK(I1,I2)-
X FDRR.JK(I1,I2))                                                  7-2
N RUOUS(I1,I2)=RUOUSI(I1,I2)                                       7-2-1
T RUOUSI(*,1)=0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/
X 0/0/0/0/0/0/0/0/0/0/0/0                                          7-2-2
T RUOUSI(*,2)=0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/
X 0/0/0/0/0/0/0/0/0/0/0/0                                          7-2-3
T RUOUSI(*,3)=0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/
X 0/0/0/0/0/0/0/0/0/0/0/0                                          7-2-4
T RUOUSI(*,4)=0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/
X 0/0/0/0/0/0/0/0/0/0/0/0                                          7-2-5
NOTE
CC         CEIL COMPARATOR
FDRR       FORCE DEPLOYMENT RATE BY REST OF WORLD(US PRODUCTION)
FDRTUS     FORCE DEPLOYMENT RATE BY US
ILP        INDUSTRY LOBBY PRESSURE
PFPRUS     PLANNED FORCE PRODUCTION BY US
PTFRTI     PAYMENT TO TRUST FUND RATE-INPUT
ROARUS     REST OF WORLD ORDERS TO US-APPROVAL RATE
ROPUS      REST OF WORLD ORDERS TO US-PROCESSED
ROWFR      REST OF WORLD FORCE REQUESTED
RUOUS      REST OF WORLD UNFILLED ORDERS HELD BY US
RUOUSI     REST OF WORLD UNFILLED ORDERS HELD BY US-INITIAL LEVEL
USFRAR     US FORCE REQUESTS APPROVAL RATE
USFRP      US FORCE REQUESTS PROCESSED
USFRRT     US FORCE REQUEST RATE
USPCFA     US PRESSURE ON CONGRESS FOR FORCE APPROPRIATIONS
USPCPR     US PLANNED CAPITAL PRODUCTION RATE
USUO       US UNFILLED ORDERS
USUOI      US UNFILLED ORDERS-INITIAL LEVEL
```

Fig. 41. Equations, Subsector VII-A

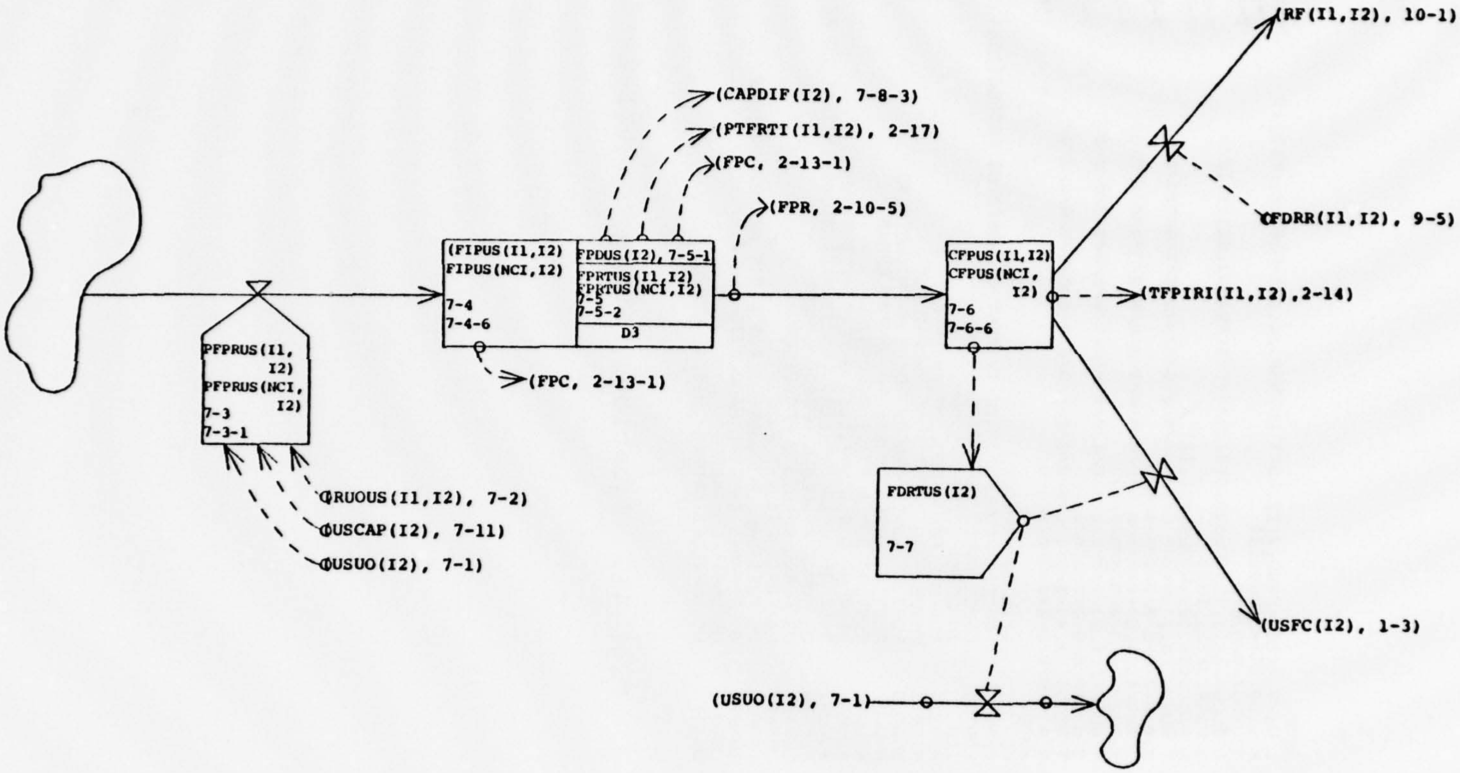


Fig. 42. Flow Diagram, Subsector VII-B

```
NOTE
R PFPRUS.KL(I1,I2)=RUOUS.K(I1,I2)*MAX(0,USCAP.K(I2)-USUO.K(I2))/
X SUMV(RUOUS.K(*,I2),1,NCNTRY)                                   7-3
R PFPRUS.KL(NCI,I2)=MIN(USCAP.K(I2),USUO.K(I2))                  7-3-1
L FIPUS.K(I1,I2)=FIPUS.J(I1,I2)+DT*(PFPRUS.JK(I1,I2)-
X FPRTUS.JK(I1,I2))                                              7-4
N FIPUS(I1,I2)=FIPUSI(I1,I2)                                     7-4-1
T FIPUSI(*,1)=0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/
X 0/0/0/0/0/0/0/0/0/0/0/0                                        7-4-2
T FIPUSI(*,2)=0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/
X 0/0/0/0/0/0/0/0/0/0/0/0                                        7-4-3
T FIPUSI(*,3)=0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/
X 0/0/0/0/0/0/0/0/0/0/0/0                                        7-4-4
T FIPUSI(*,4)=0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/
X 0/0/0/0/0/0/0/0/0/0/0/0                                        7-4-5
L FIPUS.K(NCI,I2)=FIPUS.J(NCI,I2)+DT*
X (PFPRUS.JK(NCI,I2)-FPRTUS.JK(NCI,I2))                          7-4-6
N FIPUS(NCI,I2)=FIPUSI(NCI,I2)                                   7-4-7
R FPRTUS.KL(I1,I2)=DELAY3(PFPRUS.JK(I1,I2),FPDUS(I2))            7-5
T FPDUS=3/3/3/3                                                  7-5-1
R FPRTUS.KL(NCI,I2)=DELAY3(PFPRUS.JK(NCI,I2),
X FPDUS(I2))                                                     7-5-2
L CFPUS.K(I1,I2)=CFPUS.J(I1,I2)+DT*(FPRTUS.JK(I1,I2)-
X FDRR.JK(I1,I2))                                                7-6
N CFPUS(I1,I2)=CFPUSI(I1,I2)                                     7-6-1
T CFPUSI(*,1)=0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/
X 0/0/0/0/0/0/0/0/0/0/0/0                                        7-6-2
T CFPUSI(*,2)=0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/
X 0/0/0/0/0/0/0/0/0/0/0/0                                        7-6-3
T CFPUSI(*,3)=0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/
X 0/0/0/0/0/0/0/0/0/0/0/0                                        7-6-4
T CFPUSI(*,4)=0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/
X 0/0/0/0/0/0/0/0/0/0/0/0                                        7-6-5
L CFPUS.K(NCI,I2)=CFPUS.J(NCI,I2)+DT*
X (FPRTUS.JK(NCI,I2)-FDRTUS.JK(I2))                              7-6-6
N CFPUS(NCI,I2)=CFPUSI(NCI,I2)                                   7-6-7
R FDRTUS.KL(I2)=CFPUS.K(NCI,I2)                                  7-7
NOTE
CFPUS      COMPLETED FORCE PRODUCTION BY US
CFPUSI     COMPLETED FORCE PRODUCTION BY US-INITIAL LEVEL
FDRR       FORCE DEPLOYMENT RATE BY REST OF WORLD
           (US PRODUCTION)
FDRTUS     FORCE DEPLOYMENT RATE BY US
FIPUS      FORCE IN PRODUCTION BY US
FIPUSI     FORCE IN PRODUCTION BY US-INITIAL LEVEL
FPDUS      FORCE PRODUCTION DELAY IN US
FPRTUS     FORCE PRODUCTION RATE BY US
ILP        INDUSTRY LOBBY PRESSURE
NCI        NUMBER OF COUNTRIES INCLUDING THE US
NCNTRY     NUMBER OF COUNTRIES
PFPRUS     PLANNED FORCE PRODUCT&ON RATE BY US
RF         REST OF WORLD FORCE INVENTORY
RUOUS      REST OF WORLD UNFILLED ORDERS HELD BY US
TFPIRI     TRUST FUND PAYMENT TO DEFENSE INDUSTRY RATE-INPUT
USCAP      US CAPITAL INVENTORY
USFC       US FORCES IN CONUS
USILDR     US DEFENSE INDUSTRY LIQUIDITY DEPLETION RATE
USLF       US LABOR FORCE
USPIRI     US PAYMENT TO DEFENSE INDUSTRY RATE-INPUT
USUO       US UNFILLED ORDERS
```

Fig. 43. Equations, Subsector VII-B

TABLE 5

RATES AND AUXILIARIES, SUBSECTOR VII-B

Name and Type	Purpose	Line	Inputs	Purpose and Effect
PFPRUS, rate Eq. 7-3	Enters materials into U.S. work-in-process.	1	USCAP	Maximum U.S. production rate
		2	USUO	U.S. Unfilled Orders are entered into production, up to a maximum of USCAP.
		3	RUOUS	After USUO is depleted, any remaining capacity is divided among foreign country orders based on each country's share of total ROW unfilled orders.

U.S. Force in Production (FIPUS), which is metered by the delay U.S. Force Production Rate (FPRTUS) into the level of completed weapons (CFPUS). Completed production is divided by country and deployed by the Rates Force Deployment by ROW (FDRR) and the U.S. (FDRTUS).

Subsector VII-C

The flow diagram for this subsector is shown in Figure 44, the equations in Figure 45, and the explanation of complex rates and auxiliaries in Table 6. This subsector produces, maintains, and retires plant capacity for U.S. defense production. Materials for new plant capacity are metered into the plants under construction level (USCIP) by the U.S. Planned Capital Production Rate (USPCPR). Work-in-process becomes capital ready for use (USCAP) through the delay U.S. Capital Production Rate (USCPR). Obsolescent capital is retired through the delay U.S. Capital Retirement Rate (USCRRT).

Sector VIII

The flow diagram for this sector is shown in Figure 46, the equations in Figure 47, and the explanation of complex rates and auxiliaries in Table 7. This sector generates and processes country requests for weapons. Requests are generated by the ROW Force Request Approval Rate (RFRART) and channeled to the level of approved requests (RFRA). Approved requests are immediately entered

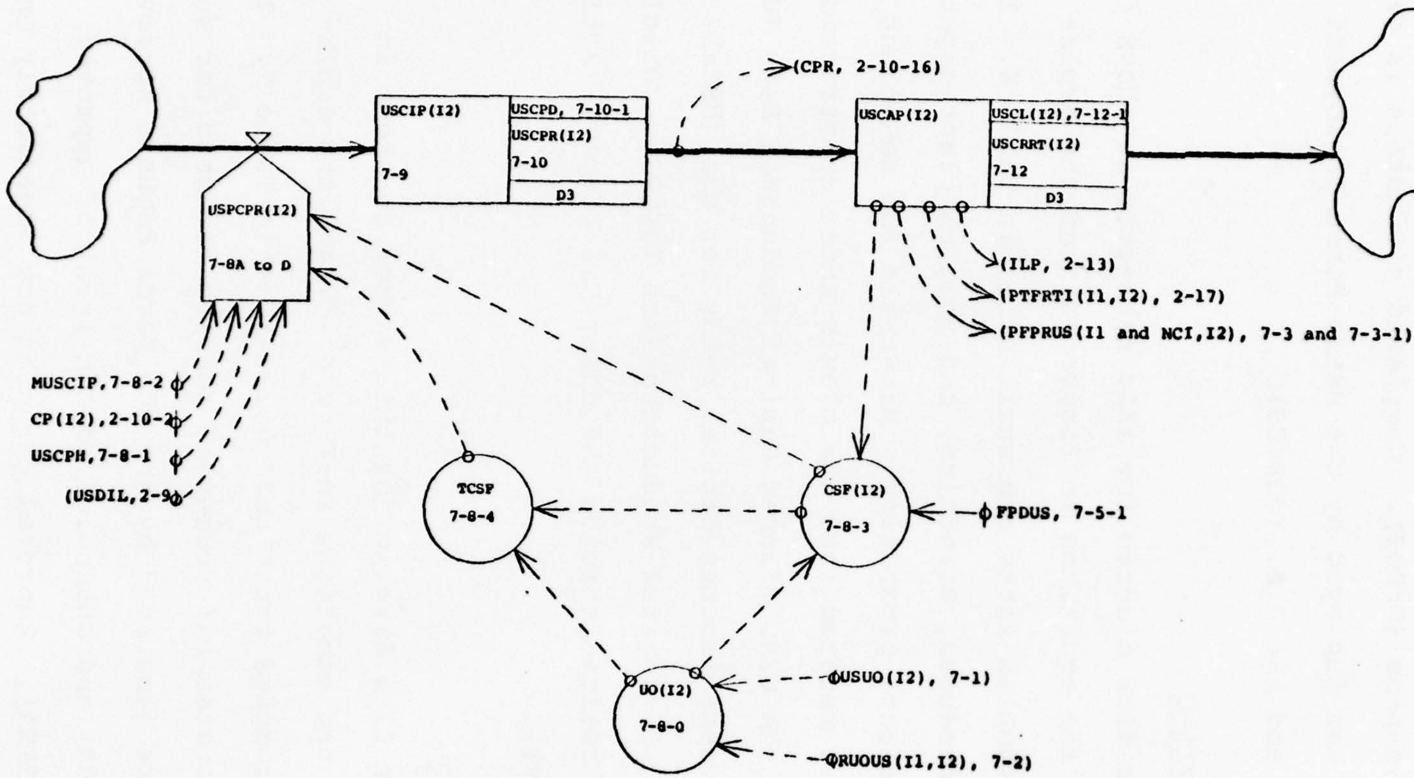


Fig. 44. Flow Diagram, Subsector VII-C

```
NOTE
R USPCPR.KL(1)=MIN(SMOOTH(CSF.K(1),USCPH),USDIL.K/CP(1)*
X MUSCIP*SMOOTH(CSF.K(1),USCPH)/SMOOTH(TCSF.K,USCPH))          7-8A
R USPCPR.KL(2)=MIN(SMOOTH(CSF.K(2),USCPH),USDIL.K/CP(2)*
X MUSCIP*SMOOTH(CSF.K(2),USCPH)/SMOOTH(TCSF.K,USCPH))          7-8B
R USPCPR.KL(3)=0                                               7-8C
R USPCPR.KL(4)=0                                               7-8D
A UO.K(I2)=USUO.K(I2)+SUMV(RUOUS.K(*,I2),1,NCNTRY)             7-8-0
C USCPH=5                                                      7-8-1
C MUSCIP=.075                                                  7-8-2
A CSF.K(I2)=UO.K(I2)/FPDUS(I2)-USCAP.K(I2)                     7-8-3
A TCSF.K=CSF.K(1)+CSF.K(2)                                     7-8-4
L USCIP.K(I2)=USCIP.J(I2)+DT*(USPCPR.JK(I2)-USCPR.JK(I2))      7-9
N USCIP(I2)=USCIPI(I2)                                         7-9-1
T USCIPI=0/0/0/0                                               7-9-2
R USCPR.KL(I2)=DELAY3(USPCPR.JK(I2),USCPD)                     7-10
C USCPD=5                                                      7-10-1
L USCAP.K(I2)=USCAP.J(I2)+DT*(USCPR.JK(I2)-USCRRT.JK(I2))      7-11
N USCAP(I2)=USCAPI(I2)                                         7-11-1
T USCAPI=1500/425/525/90                                       7-11-2
R USCRRT.KL(I2)=DELAY3(USCPR.JK(I2),USCL(I2))                  7-12
T USCL=25/30/20/10                                             7-12-1
NOTE
CP        CAPITAL PRICE
CSF       CAPITAL SHORTFALL
ILP       INDUSTRY LOBBY PRESSURE
MUSCIP    MAXIMUM PROPORTION OF US INDUSTRY LIQUIDITY
          AVAILABLE FOR CAPITAL PRODUCTION
NCNTRY    NUMBER OF COUNTRIES
PFPRUS    PLANNED FORCE PRODUCTION RATE BY US
PTFRTI    PAYMENT TO TRUST FUND RATE-INPUT
RUOUS     REST OF WORLD UNFILLED ORDERS HELD BY US
TCSF      TOTAL CAPITAL SHORTFALL
UO        UNFILLED ORDERS
USCAP     US CAPITAL INVENTORY
USCAPI    US CAPITAL INVENTORY-INITIAL LEVEL
USCIP     US CAPITAL IN PRODUCTION
USCIPI    US CAPITAL IN PRODUCTION-INITIAL LEVEL
USCL      US CAPITAL LIFE
USCPD     US CAPITAL PRODUCTION DELAY
USCPH     US CAPITAL PRODUCTION PLANNING HORIZION
USCPR     US CAPITAL PRODUCTION RATE
USCRRT    US CAPITAL RETIREMENT RATE
USDIL     US DEFENSE INDUSTRY LIQUIDITY
USILDR    US DEFENSE INDUSTRY LIQUIDITY DEPLETION RATE
USPCPR    US PLANNED CAPITAL PRODUCTION RATE
USUO      US UNFILLED ORDERS
```

Fig. 45. Equations, Subsector VII-C

TABLE 6

RATES AND AUXILIARIES, SUBSECTOR VII-C

Name and Type	Purpose	Line	Inputs	Purpose and Effect
USPCPR, rate Eq. 7-8A to D	Enters materials into capital work-in-process.	1	CSF	The difference between unfilled orders (UO) and total U.S. capacity (USCAP) is averaged over USCPH years.
		2	USCAP, CP, MUSCIP	Calculates total money available for expansion.
		3	TCSF	Along with CSF, calculates money allocated from that available to each of tactical nuclear weapons capital expansion and state-of-the-art capital expansion.
		4		The minimum of lines 1 and 3 is taken to insure their industry neither orders more than it can afford nor more than it needs.
		5		The rates for modern and dated capital expansion are assumed to be zero.

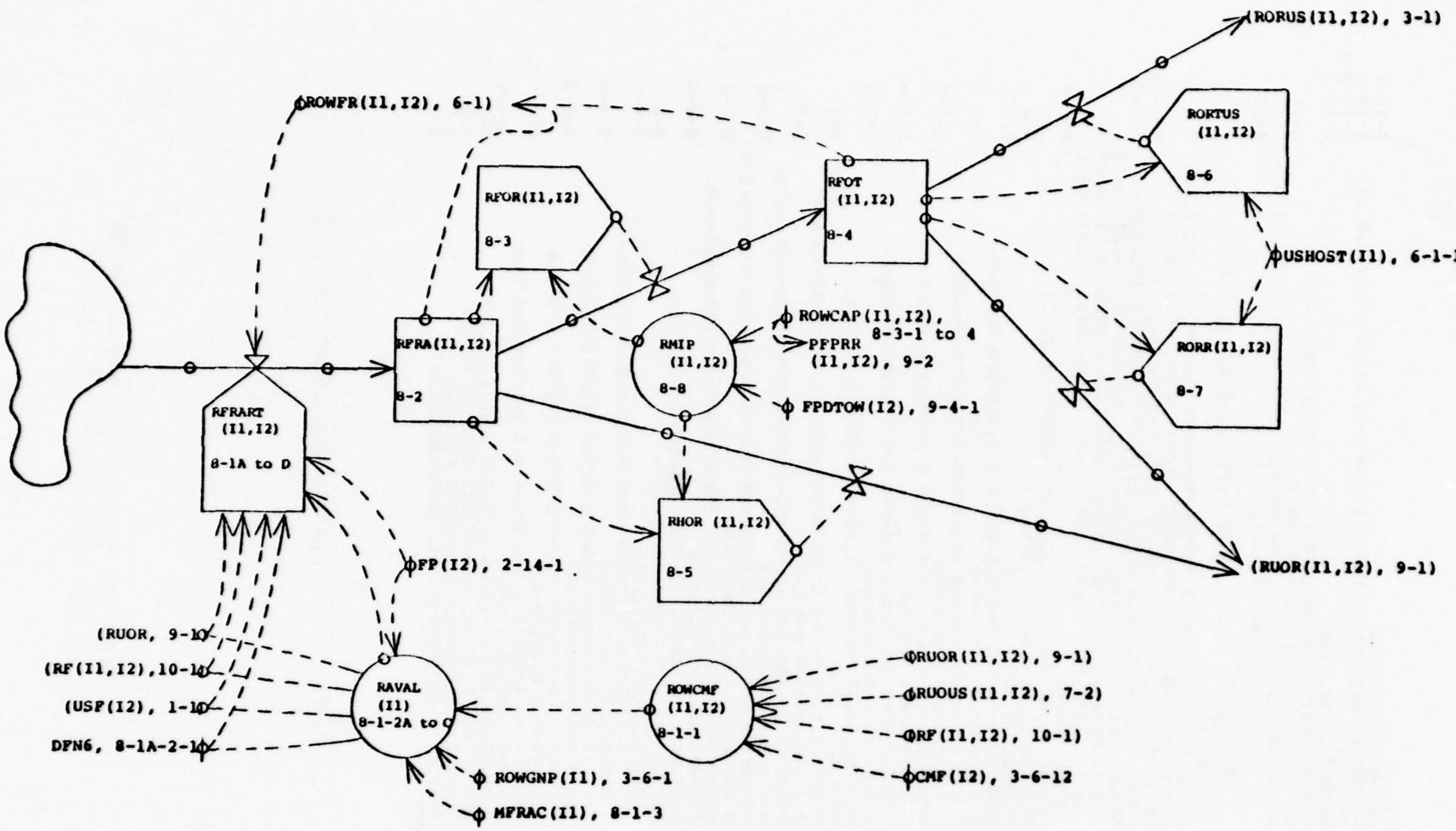


Fig. 46. Flow Diagram, Sector VIII

```
NOTE
R RFRART.KL(I5,1)=0                                                     8-1A-1
R RFRART.KL(6,1)=MIN(0,USF.K(1)*DNF6-RF.K(6,1)-RUOR.K(6,1))            8-1A-2
C DNF6=.5                                                              8-1A-2-1
R RFRART.KL(I6,1)=0                                                     8-1A-3
R RFRART.KL(I1,2)=MIN(ROWFR.K(I1),MAX(0,(ROWFR.K(I1)*
X FP(3)-RAVAL.K(I1))/(FP(3)-FP(2))))                                    8-1B
R RFRART.KL(I1,3)=MAX(0,MIN((RAVAL.K(I1)-FP(2)*ROWFR.K(I1))/
X (FP(3)-FP(2)),RAVAL.K(I1)/FP(3)))                                     8-1C
R RFRART.KL(I1,4)=0                                                     8-1D
A ROWCMF.K(I1,I2)=CMF(I2)*(RF.K(I1,I2)+RUOUS.K(I1,I2)+
X RUOR.K(I1,I2))                                                        8-1-1
A RAVAL.K(I5)=ROWGNP(I5)*MFRAC(I5)-SUMV(ROWCMF.K(I5,*),1,4)             8-1-2A
A RAVAL.K(6)=ROWGNP(6)*MFRAC(6)-SUMV(ROWCMF.K(6,*),1,4)-
X FP(1)*MIN(0,USF.K(1)*DNF6-RF.K(6,1)-RUOR.K(6,1))                      8-1-2B
A RAVAL.K(I6)=ROWGNP(I6)*MFRAC(I6)-SUMV(ROWCMF.K(I6,*),1,4)             8-1-2C
T MFRAC=.0011/.0019/.0022/.0004/.0011/.0026/.0037/.0022/.0019/
X .0011/.0044/.0019/.0007/.0009/.0004/.0007/.0022/.0019/.0007/
X .0011/.0007/.0019/.0007/.0007/.0041/.0011/.0119/.0033/.0011/
X .0030/.0037/0                                                         8-1-3
L RFRA.K(I1,I2)=RFRA.J(I1,I2)+DT*(RFRART.JK(I1,I2)-
X RFOR.JK(I1,I2)-RHOR.JK(I1,I2))                                        8-2
N RFRA(I1,I2)=RFRAI(I1,I2)                                              8-2-1
T RFRAI(*,1)=0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/
X 0/0/0/0/0/0/0/0/0/0/0/0                                               8-2-2
T RFRAI(*,2)=0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/
X 0/0/0/0/0/0/0/0/0/0/0/0                                               8-2-3
T RFRAI(*,3)=0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/
X 0/0/0/0/0/0/0/0/0/0/0/0                                               8-2-4
T RFRAI(*,4)=0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/
X 0/0/0/0/0/0/0/0/0/0/0/0                                               8-2-5
R RFOR.KL(I1,I2)=RFRA.K(I1,I2)-MIN(RFRA.K(I1,I2),
X RMIP.K(I1,I2))                                                        8-3
T ROWCAP(*,1)=0/0/0/0/0/750/0/0/0/0/0/0/0/0/0/0/0/0/
X 0/0/0/0/0/0/0/0/0/0/0/0                                               8-3-1
T ROWCAP(*,2)=200/0/0/125/0/480/0/0/0/0/0/0/0/0/0/0/0/0/0/
X 0/0/0/0/0/0/0/0/0/0/0/0                                               8-3-2
T ROWCAP(*,3)=530/0/0/125/30/500/0/0/45/0/0/0/0/0/0/0/0/0/0/
X 0/0/0/0/0/0/120/0/30/0/0/0                                            8-3-3
T ROWCAP(*,4)=50/0/0/0/0/895/250/0/0/0/0/0/0/0/0/0/0/0/0/
X 0/0/0/0/0/0/0/0/45/0/0/0                                              8-3-4
L RFOT.K(I1,I2)=RFOT.J(I1,I2)+DT*(RFOR.JK(I1,I2)-
X RORTUS.JK(I1,I2)-RORR.JK(I1,I2))                                      8-4
N RFOT(I1,I2)=RFOTI(I1,I2)                                              8-4-1
T RFOTI(*,1)=0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/
X 0/0/0/0/0/0/0/0/0/0/0/0                                               8-4-2
T RFOTI(*,2)=0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/
X 0/0/0/0/0/0/0/0/0/0/0/0                                               8-4-3
T RFOTI(*,3)=0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/
X 0/0/0/0/0/0/0/0/0/0/0/0                                               8-4-4
T RFOTI(*,4)=0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/
X 0/0/0/0/0/0/0/0/0/0/0/0                                               8-4-5
R RHOR.KL(I1,I2)=MIN(RFRA.K(I1,I2),RMIP.K(I1,I2))                       8-5
R RORTUS.KL(I1,I2)=(1-USHOST(I1))*RFOT.K(I1,I2)                         8-6
R RORR.KL(I1,I2)=USHOST(I1)*RFOT.K(I1,I2)                               8-7
A RMIP.K(I1,I2)=ROWCAP.K(I1,I2)*FPDROW(I2)                              8-8
NOTE
```

Fig. 47. Equations, Sector VIII

NOTE	
CMF	UNIT COST OF MAINTAINING FORCE
DNF6	DESIRED NUCLEAR FRACTION FOR SOVIET UNION
FP	FORCE PRICE
FPDROW	FORCE PRODUCTION DELAY-REST OF WORLD
MFRAC	MILITARY FRACTION OF GROSS NATIONAL PRODUCT
RAVAL	REST OF WORLD FUNDS AVAILABLE
RF	REST OF WORLD FORCE INVENTORY
RFOR	REST OF WORLD FOREIGN ORDERING RATE
RFOT	REST OF WORLD FOREIGN ORDERS TOTAL
RFOTI	REST OF WORLD FOREIGN ORDERS TOTAL-INITIAL LEVEL
RFRA	REST OF WORLD FORCE REQUESTS - APPROVED
RFRAI	REST OF WORLD FORCE REQUESTS - APPROVED - INITIAL LEVEL
RFRART	REST OF WORLD FORCE REQUEST APPROVAL RATE
RHOR	REST OF WORLD HOME ORDERING RATE
RMIP	REST OF WORLD MAXIMUM FORCE IN PRODUCTION
RORR	REST OF WORLD ORDERING RATE TO REST OF WORLD
(EXCEPT HOME)	
RORTUS	REST OF WORLD ORDERING RATE TO US
RORUS	REST OF WORLD ORDERS RECEIVED BY US
ROWCAP	REST OF WORLD CAPITAL INVENTORY
ROWCMF	REST OF WORLD COST OF MAINTAINING FORCE
ROWFR	REST OF WORLD FORCE REQUESTED
ROWGNP	REST OF WORLD GROSS NATIONAL PRODUCT
RUOR	REST OF WORLD UNFILLED ORDERS HELD BY REST OF WORLD
RUOUS	REST OF WORLD UNFILLED ORDERS HELD BY US

Fig. 47--Continued

TABLE 7

RATES AND AUXILIARIES, SECTOR VIII

Name and Type	Purpose	Line	Inputs	Purpose and Effect
RFRART, rate Eq. 8-1A to D	Meters approved force requests, broken out by technology level	1	RAVAL	Money available for acquisition is calculated by taking a percentage (MFRAC) of ROWGNP, then subtracting the cost of maintaining current forces plus forces already on order.
		2		Money available is divided between state-of-the-art and modern acquisition based on the total force request (ROWFR).
		3		If insufficient money exists to buy all state-of-the-art, acquisition is shifted one unit at a time to modern until the fiscal constraint is met.
		4		If all acquisition has been shifted to modern, and the constraint has not been met, acquisition is reduced until the constraint is met.

TABLE 7--Continued

Name and Type	Purpose	Line	Inputs	Purpose and Effect
		5		The request approval rates for tactical nuclear weapons (except for the Soviet Union) and dated equipment are assumed to be zero. The Soviet Union may produce and deploy tactical nuclear weapons. The algorithm employed is to make RFRART (6,1) equal to the difference, if any, between a given percentage (DNF6) of U.S. tactical nuclear weapons and the current Soviet inventory (including units on order). Monies required to purchase new tactical nuclear weapons are subtracted from RAVAL, and the amount remaining is used to compute conventional acquisition rates.

into home production (capacity allowing) by the ROW Home Ordering Rate (RHOR) and become unfilled orders (RUOR). Requests which would have to wait an excessive period to be completed at home become foreign orders (RFOT) metered by the ROW Foreign Ordering Rate (RFOR). Foreign orders are divided by ROW Ordering Rate to the U.S. (RORTUS) and the ROW Ordering Rate to ROW (RORR) between the U.S. (where they become received orders) and other producing countries based on perceived U.S. hostility (USHOST). For the purposes of this model, orders sent to other producing countries are channeled into RUOR.

Sector IX

The flow diagram for this sector is shown in Figure 48, and the equations in Figure 49. This sector accumulates unfilled orders for ROW production (RUOR). This level drives the planned force production rate (PFPRR), which divides capacity (ROWCAP) among customers based on the proportion of their unfilled orders to the total unfilled orders. Work-in-process (FIPR), when completed, is deployed through the delay ROW Force Production Rate (FPRR) to country active forces inventory. The delay FPRR also depletes unfilled orders (RUOR). The sector also contains the ROW Force Deployment Rate (FDRR), which deploys completed U.S. production to foreign customers. ROW Force Deployment Rate (FDRR) is aggregated into a U.S. arms transfer rate (ATR).

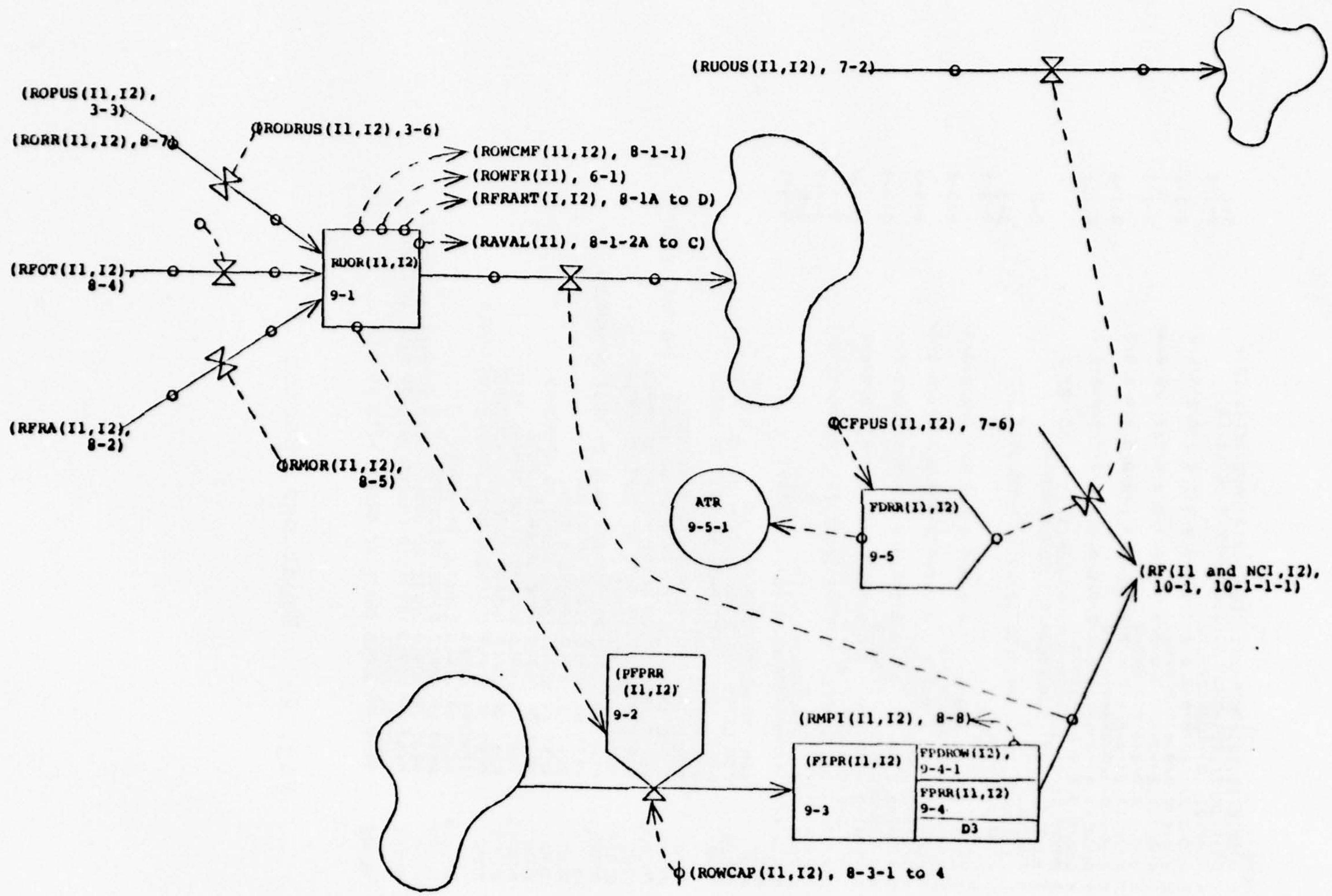


Fig. 48. Flow Diagram, Sector IX

```
NOTE
L RUOR.K(I1,I2)=RUOR.J(I1,I2)+DT*(RODRUS.JK(I1,I2)+
X RORR.JK(I1,I2)+RHOR.JK(I1,I2)-FPRR.JK(I1,I2))                  9-1
N RUOR(I1,I2)=RUORI(I1,I2)                                        9-1-1
T RUORI(*,1)=0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/
X 0/0/0/0/0/0/0/0/0/0/0                                           9-1-2
T RUORI(*,2)=0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/
X 0/0/0/0/0/0/0/0/0/0/0                                           9-1-3
T RUORI(*,3)=0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/
X 0/0/0/0/0/0/0/0/0/0/0                                           9-1-4
T RUORI(*,4)=0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/
X 0/0/0/0/0/0/0/0/0/0/0                                           9-1-5
R PFPRR.KL(I1,I2)=MIN(SUMV(ROWCAP(*,I2),1,NCNTRY)*
X RUOR.K(I1,I2)/SUMV(RUOR.K(*,I2),1,NCNTRY),
X RUOR.K(I1,I2))                                                  9-2
L FIPR.K(I1,I2)=FIPR.J(I1,I2)+DT*(PFPRR.JK(I1,I2)-
X FPRR.JK(I1,I2))                                                 9-3
N FIPR(I1,I2)=FIPRI(I1,I2)                                        9-3-1
T FIPRI(*,1)=0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/
X 0/0/0/0/0/0/0/0/0/0/0                                           9-3-2
T FIPRI(*,2)=0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/
X 0/0/0/0/0/0/0/0/0/0/0                                           9-3-3
T FIPRI(*,3)=0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/
X 0/0/0/0/0/0/0/0/0/0/0                                           9-3-4
T FIPRI(*,4)=0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/
X 0/0/0/0/0/0/0/0/0/0/0                                           9-3-5
R FPRR.KL(I1,I2)=DELAY3(PFPRR.JK(I1,I2),FPDROW(I2))               9-4
T FPDROW=3/3/3/3                                                  9-4-1
R FDRR.KL(I1,I2)=CFPUS.K(I1,I2)                                   9-5
S ATR.K(I2)=SUMV(FDRR.JK(*,I2),1,NCNTRY)                          9-5-1
NOTE
ATR       ARMS TRANSFER RATE FROM US
CFPUS     COMPLETED FORCE PRODUCTION BY US
FDRR      FORCE DEPLOYMENT RATE BY REST OF WORLD
          (US PRODUCTION)
FIPR      FORCE IN PRODUCTION BY REST OF WORLD
FIPRI     FORCE IN PRODUCTION BY REST OF WORLD - INITIAL LEVEL
FPDROW    FORCE PRODUCTION DELAY - REST OF WORLD
FPRR      FORCE PRODUCTION RATE BY REST OF WORLD
NCNTRY    NUMBER OF COUNTRIES
PFPRR     PLANNED FORCE PRODUCTION RATE BY REST OF WORLD
RF        REST OF WORLD FORCE INVENTORY
RFOT      REST OF WORLD ORDERS - TOTAL
RFRA      REST OF WORLD FORCE REQUESTS APPROVED
RHOR      REST OF WORLD HOME ORDERING RATE
RODRUS    REST OF WORLD ORDERS TO US DENIAL RATE
ROPUS     REST OF WORLD ORDERS TO US - PROCESSED
RORR      REST OF WORLD ORDERING RATE TO REST OF WORLD
          (EXCEPT HOME)
ROWCAP    REST OF WORLD CAPITAL INVENTORY
ROWFR     REST OF WORLD FORCE REQUESTED
RUOR      REST OF WORLD UNFILLED ORDERS HELD BY REST OF WORLD
RUORI     REST OF WORLD UNFILLED ORDERS HELD BY REST OF WORLD -
          INITIAL LEVEL
RUOUS     REST OF WORLD UNFILLED ORDERS HELD BY US
```

Fig. 49. Equations, Sector IX

Sector X

The flow diagram for this sector is shown in Figure 50, and the equations in Figure 51. This sector contains only the level of ROW current force inventory (RF), which received new production from the U.S. and ROW via the deployment rates RDRR and RPRR. Weapons become obsolescent through the delay RFRR.

Summary

The development of the arms transfer model is now complete. Sector I was presented in its entirety in Chapter III. Chapter IV detailed the conceptual development of Sectors II through X, and this chapter has presented the flow diagrams and equations for the same sectors. Chapter VI will include a summary of this research effort, conclusions, and recommendations for further research.

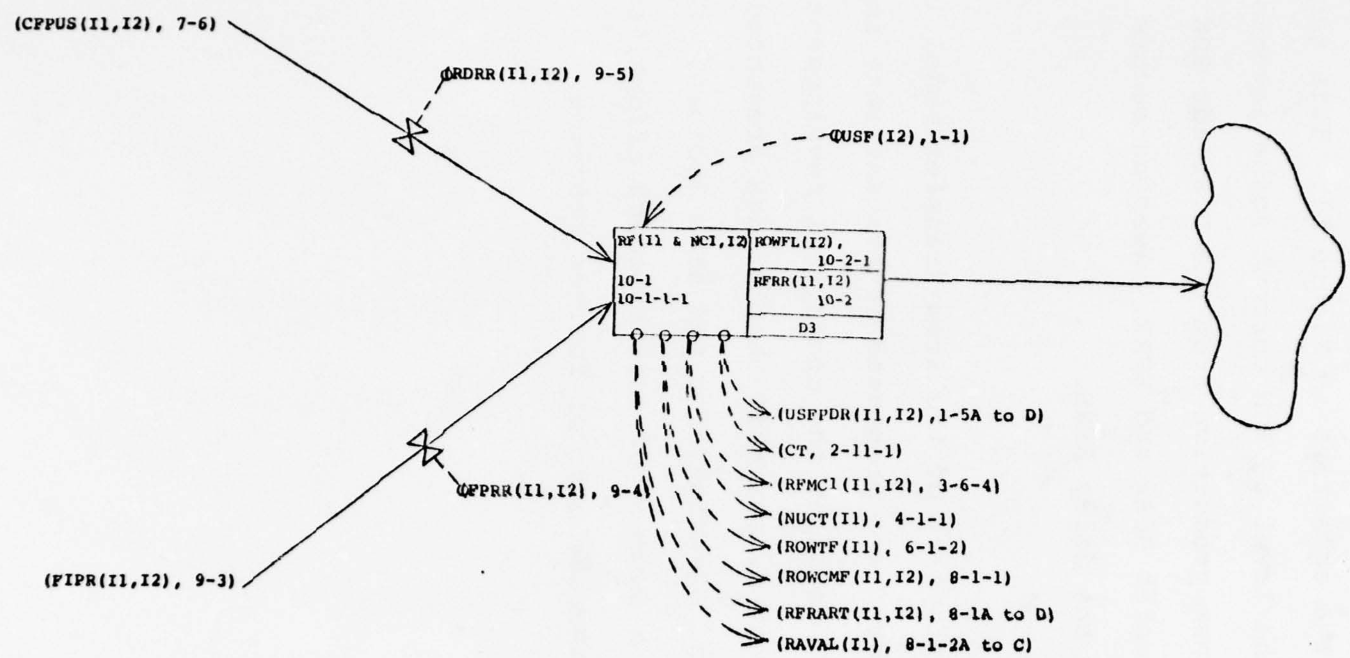


Fig. 50. Flow Diagram, Sector X

```
NOTE
L RF.K(I1,I2)=RF.J(I1,I2)+DT*(FDRR.JK(I1,I2)+
X FPRR.JK(I1,I2)-RFRR.JK(I1,I2))
L RF.K(NCI,I2)=USF.J(I2)                                        10-1
N RF(I1,I2)=RFI(I1,I2)                                          10-1-0
N RF(NCI,I2)=USFC(I2)+SUMV(USFO(*,I2),1,32)                     10-1-1
T RFI(*,1)=0/0/0/0/0/3500/0/0/0/0/0/0/0/0/0/0/0/0/0/0/          10-1-1-1
X 0/0/0/0/0/0/0/0/0/0/0/0
T RFI(*,2)=249/39/0/9/22/1532/0/0/0/0/0/0/0/0/3/0/48/0/0/0/     10-1-2
X 20/0/12/21/0/25/56/0/20/142/0
T RFI(*,3)=1671/178/221/248/48/1078/20/198/209/13/30/67/30/0/   10-1-3
X 11/18/0/36/12/3/4/14/0/65/135/20/250/410/100/169/150/0
T RFI(*,4)=487/0/80/87/18/3347/5630/48/90/19/270/18/51/0/0/16/  10-1-4
X 148/28/60/19/4/79/22/60/278/12/250/175/530/54/416/0
R RFRR.KL(I1,I2)=DELAY3((FDRR.JK(I1,I2)+FPRR.JK(I1,I2)),        10-1-5
X ROWFL(I2))
T ROWFL=5/15/10/5                                               10-2
NOTE                                                            10-2-1
CFPUS     COMPLETED FORCE PRODUCTION BY US
FDRR      FORCE DEPLOYMENT RATE BY REST OF WORLD
(US PRODUCTION)
FIPR      FORCE IN PRODUCTION BY REST OF WORLD
FPRR      FORCE PRODUCTION RATE BY REST OF WORLD
RF        REST OF WORLD FORCE INVENTORY
RFI       REST OF WORLD FORCE INVENTORY - INITIAL LEVEL
RFRART    REST OF WORLD FORCE REQUEST APPROVAL RATE
RFRR      REST OF WORLD FORCE RETIREMENT PATE
ROWFL     REST OF WORLD FORCE INVENTORY LIFE
ROWFR     REST OF WORLD FORCE REQUESTED
USFODR    US FORCES OVERSEAS DEPLOYMENT RATE
USFRRT    US FORCE REQUEST RATE
USI       US INCLINATION TO APPROVE ARMS TRANSFERS
USPSFA    US PRESSUPE ON CONGRESS FOR FORCE APPROPRIATIONS
PLOT ATR=P/RI=I/USRGNP=P/EUSBT=B
SPEC DT=.05/LENGTH=1983/PLTPER=.25
RUN ARMS TRANSFER MODEL
```

Fig. 51. Equations, Sector X

CHAPTER VI

SUMMARY, RECOMMENDATIONS AND CONCLUSIONS

Chapter I through V contained the basis for this research of arms transfers, the methodology used, and the development of the conceptual and mathematical models. All of this was guided by the research objectives in Chapter I. This chapter comprises a summary of the research effort in terms of the objectives, a short discussion of conclusions and recommendations for further research.

Summary

Objective 1: To identify and describe the components of the arms transfer system; and

Objective 2: To describe the relationships between these components, including the system's decision structure. These objectives were accomplished together. Firstly, the basic elements of the arms transfer system and their general relationships were identified through a literature review and informal discussions with Air Force Institute of Technology faculty members. Secondly, a series of influence diagrams were drawn which portrayed the identified elements and relationships and which comprised the authors' hypothesis about the basic structure of the arms transfer system.

Thirdly, a series of formal interviews was conducted with persons involved with arms transfers at a high policy-making and implementation level. The purpose of these interviews was to confirm the content of the influence diagrams and to gain more information. This information was incorporated into the influence diagrams. This entire process culminated in the influence diagrams displayed in Chapters III and IV.

Objective 3: To construct a mathematical model which will represent the relationships between system components. This objective was accomplished through the operational definition of previously identified system elements and the translation of the influence diagrams into flow diagrams using the operationally defined variables. The flow diagrams were presented in Chapters III and V.

Objective 4: To translate the mathematical model into a dynamic system model suitable for computer processing. This objective was accomplished through the writing of DYNAMO equations from the flow diagrams. The gathering and occasional estimation of numerical constants and initial conditions contributed to the completion of this objective. Also, six external functions (see Appendix D) were written to perform operations which DYNAMO could not do.

Objective 5: To generate the behavior of the arms transfer computer model over time, given certain sets of arms transfer policies; and

Objective 6: To validate the computer model by comparisons of predicted behavior with real world behavior; and

Objective 7: To use the computer model to suggest changes to U.S. arms transfer policies and policy-making structures which will further the realization of U.S. national interests and objectives. The model equations were submitted to the Air Force Logistics Command's Honeywell 635 (CREATE) computer at Wright-Patterson Air Force Base, Ohio. After several unsuccessful computer runs, the model was discovered to be too large for the Honeywell computer. Therefore, the last three objectives were not accomplished. Recommendations for the accomplishment of these objectives are addressed below.

The accomplishment of the research objectives led directly to the answering of the research questions. A policy model of the arms transfer system can be and was developed. Although the extent to which the behavior of the model captures the behavior of the arms transfer system is not known, a number of conclusions were drawn from the systems analysis which culminated in the model.

Conclusions

The conclusions drawn from the systems analysis fall into the categories of general conclusions and specific observations. The general conclusions concern information

requirements, system structure, and performance measures. The specific observations concern the trust fund and the arms transfer ceiling.

The arms transfer model incorporates a variety of information types required for arms transfer decisionmaking. All of the required information is available in some form, either qualitative or quantitative. To be used in the model, qualitative information had to be quantified or estimated on some scale. This was true, for example, of the key importance and hostility factors. It was also true of such abstract concepts as threat, which was defined as inventory times hostility. In any event, all information needed for arms transfer decisionmaking is available; for the purpose of modeling, qualitative information and concepts must be quantified on some basis agreeable to the decisionmaker.

The structure of the arms transfer system is fundamentally straightforward. It is, in fact, a simple production system except in two respects: Threat determination (addressed above) and the process of deciding whether or not to sell arms. In the model, the latter is represented by a single auxiliary (U.S. Inclination to Approve Orders) because there is only one decision to be made for each order. However, the decisionmaking organization of the U.S. Government does not correspond to the process described. Perhaps as many as eleven separate agencies make

their own analyses of each order and the consequences of approval, and any one of up to five persons may make the final decision. Thus, what is essentially a structurally simple process has become fragmented and complicated.

One reason for the fragmentation of decisionmaking is the lack of clear performance objectives for arms transfer policy. Even though the U.S. Government has enunciated a number of qualitative goals, no method apparently exists to evaluate progress toward these goals or to establish standards. The performance measure used in the model is instability, defined as the sum of all incremental force requests. The time behavior of this quantity can be used to assess the effect over time of a given arms transfer policy. Instability and perhaps other performance measures are necessary for evaluation of progress.

In addition to the general conclusions above, two specific observations were made. The first concerned the trust fund. The fact that payments into the fund do not necessarily equal payments out of the fund in a calendar quarter has concerned both the U.S. and foreign governments. But this lack of quarterly balancing is not surprising, given the flow diagram of the model. It shows that the payments into the trust fund depend on planned production rate, while the payments out depend on actual production rate. Thus, to the extent that production cannot be accurately predicted, the trust fund will not always balance.

The second specific observation concerned the arms transfer ceiling. This is an artificial constraint on the system. Such constraints can cause a system to behave in unusual and unexpected ways as the pressures contained by the constraint seek an outlet. In this case, however, no pressures build since customer countries can turn to other producers. Thus, in the short run, the ceiling constitutes nothing more than a delay. In the long run, it may lead to other producers constraining their sales, in which case part of the structure of the model will be valid no longer.

Having made a number of conclusions and observations from the system analysis, the authors set forth recommendations which, if implemented, should enhance the utility of the arms transfer model to the decisionmaker.

Recommendations for Further Research

1. The model should be run on a computer of approximately 200 kilobytes of core storage. The initial runs should replicate system behavior for a minimum of three policies:

   a. Current arms transfer policy

   b. Policy of no restraint

   c. Policy of no transfers.

Later runs could investigate other policies or elements of the current policy.

2. The computer model should be validated by comparison of output to available historical data and by discussion of the output with decisionmakers.

3. After validation, the model could be used to investigate arms transfer policy in detail. This investigation could point to the need for policy changes and structural changes in the U.S. Government's arms transfer apparatus. These would come about as decisionmakers become more familiar with the operation of the arms transfer system.

When these recommendations are followed, the answer to the research question will be complete. At that time, the arms transfer decisionmaker will have a tool which will assess the impact of arms transfer policies upon U.S. national security, foreign relations, and economic conditions. This assessment should enable the decisionmaker to more clearly understand the arms transfer system.

APPENDIXES

APPENDIX A

INTERVIEW GUIDE

ARMS TRANSFER POLICY MODEL

Project Overview

Top level strategic planners in the United States Government are becoming increasingly concerned with the overall consequences of U.S. arms transfers. The arms transfer process plays a significant role in the political, economic, and military affairs of the entire world, and is, consequently, subject to constant criticism and review from many quarters. Because of the diversity of opinion about arms transfers, it is virtually impossible to devise a concise policy that will satisfy everyone.

This project is an attempt to bring all of the significant variables concerning arms transfers together to form a dynamic model of the arms transfer system. While this model will not be able to produce policies which will keep all interested parties satisfied, it should depict the consequences of arms transfer decisions in terms of all of the major variables. These depictions should help decision takers to choose from among proposed decision alternatives.

The model should also facilitate examining policies, such as the dollar ceiling, in terms of impact on the strategic position, foreign relations, and economy of the United States. This capability should help decision takers choose policies which best serve the interests of the United States.

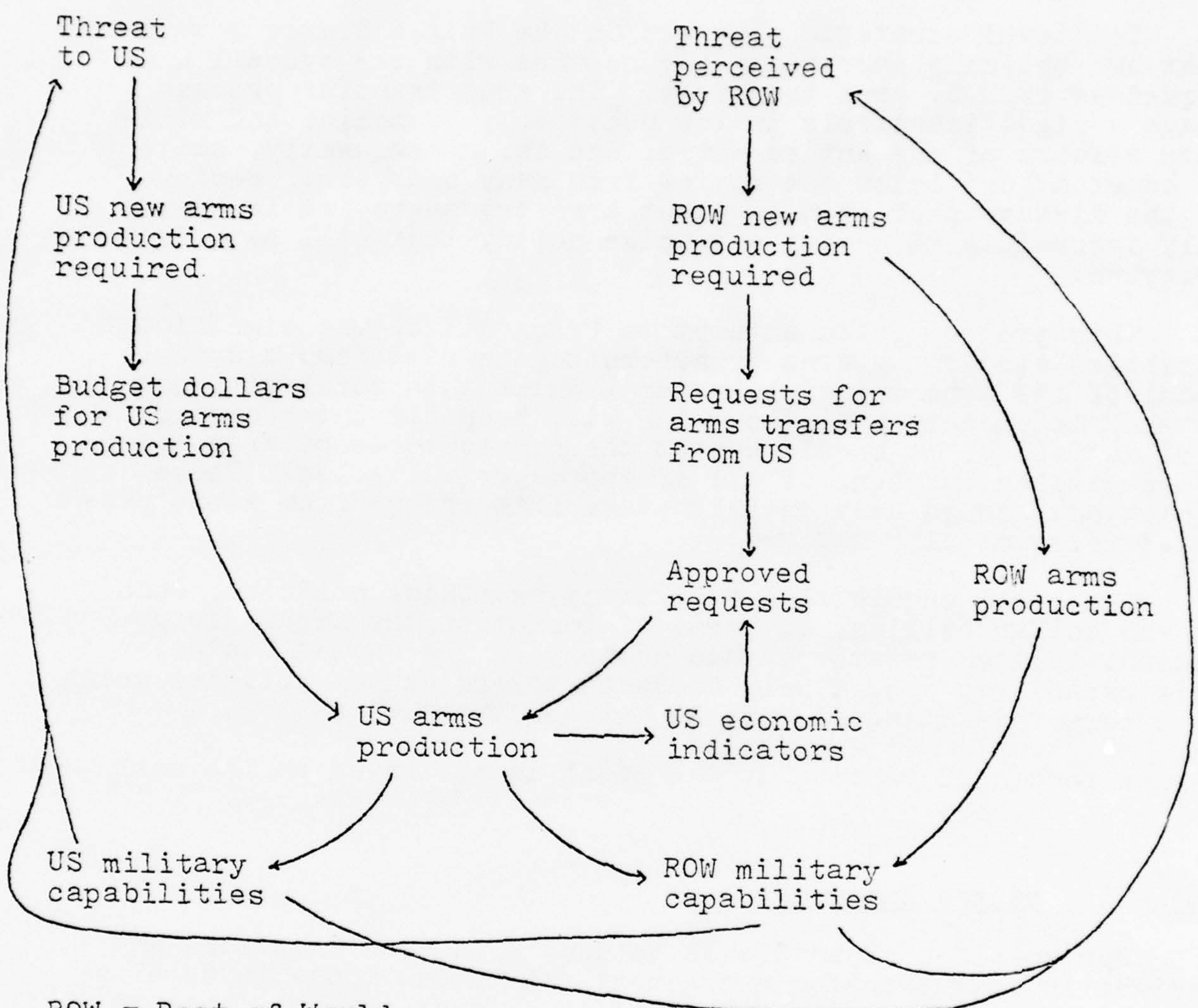
A condensed version of the model is portrayed on the next page.

Objective of the Interview

Our specific objective is to draw upon your knowledge and insight in arms transfer management and to use these in developing a policy model. Also, we want to discuss several concepts of the arms transfer process with you to validate our understanding of them.

If you wish, you will be given information about the progress of the project and a copy of the final report.

CONDENSED ARMS TRANSFER POLICY MODEL



ROW = Rest of World

This diagram represents a very brief abstract of the Arms Transfer Policy Model. The arrows depicted represent lines of influence between model components. The primary purpose of this interview is to acquire information which will permit us to precisely define the arrows above.

INTERVIEW GUIDE

1. Very broadly, what part do you play in arms transfers?

2. In your mind, why does the US transfer arms?

3. How effectively does the US accomplish this through arms transfers? How do you know?

4. What specific goals do you have with regard to the arms transfer process?

5. How did you arrive at these goals?

6. In your view, are these goals being attained? How do you know?

7. What are the most important decisions you are called upon to make with regard to arms transfers?

8. Do you ever receive feedback on the consequences of your decisions? What?

9. What are the key variables in these decisions?

10. What information do you need about these variables?

11. Is all of this information readily available to you?

12. How up-to-date is the information you receive? How reliable?

13. Where do you get your information?

14. What specific problems are you aware of in the arms transfer process?

15. Do you know of any other points that might be of use to us in our project?

16. What other persons involved in the arms transfer process would you suggest we see?

APPENDIX B

LIST OF COUNTRIES

No.	Name	Includes	Method of Creation
1.	NATO	Western Europe	Aggregation
2.	Greece	Greece	Direct
3.	Turkey	Turkey	Direct
4.	Japan	Japan	Direct
5.	Australia	Australia, New Zealand	Aggregation
6.	USSR	USSR, Eastern Europe, Mongolia	Aggregation
7.	China	China, N. Korea	Aggregation
8.	S. Korea	S. Korea	Direct
9.	Taiwan	Taiwan	Direct
10.	ASEAN	Malaysia, Thailand, Indonesia, Philippines, Singapore	Aggregation
11.	Vietnam	Vietnam, Laos, Cambodia	Aggregation
12.	Peru	Peru	Direct
13.	Chile	Chile, Bolivia, Ecuador	Aggregation

No.	Name	Includes	Method of Creation
14.	Honduras	Honduras	Direct
15.	Guatemala	Guatemala	Direct
16.	Argentina	(Typical Latin American Country)	Average
17.	Cuba	Cuba	Direct
18.	South Africa	South Africa, Zimbabwe/Rhodesia	Aggregation
19.	Zambia	(Typical Black African Confrontation Country)	Average
20.	Nigeria	(Typical Black African Neutral Country)	Average
21.	Kenya	Kenya	Direct
22.	Ethiopia	Ethiopia, Somalia	Aggregation
23.	Sudan	Sudan, Chad, Niger	Average
24.	Libya	Libya, Algeria	Average
25.	Egypt	Egypt	Direct
26.	Morocco	Morocco, Tunisia	Average

No.	Name	Includes	Method of Creation
27.	Israel	Israel	Direct
28.	Iran	Iran, Pakistan	Average
29.	India	India	Direct
30.	Saudi Arabia	Arabian Peninsula, Jordan	Aggregation
31.	Iraq	Iraq, Syria, Lebanon	Aggregation
32.	Dummy Country	(To Fill Our Neighbor Array)	---
33.	United States	United States, Canada	Aggregation

APPENDIX C

VALUE OF CONSTANTS AND INITIAL CONDITIONS

Symbol	Name	Eq. No.	Calculation and Source
		A. Constants	
CEILT	Ceiling Tabe	3-10-1	FY79 ceiling (37) reduced by 8%/year for 10 years
CMF	Cost of Maintaining Force	3-6-12	Proportionate share of FY 79 USAF Major Force Program II, per tactical combat aircraft (14)
CMUSFO	Cost of Maintaining U.S. Force Overseas	5-5-3	See CMF
CP	Capital Price	2-10-2	Dollar value of portion of capital expansion in aircraft industry devoted to tactical combat aircraft, per aircraft per year (33)
DAGR	U.S. Desired Annual GNP Growth Rate	2-12-1	Estimate
DC	Disbursement Constat	2-10-1	Estimate
DEP	Desired Employment Percentage	2-12-2	Estimate
DFGR	U.S. Desired Force Growth Rate	2-12-7	Estimate

Symbol	Name	Eq. No.	Calculation and Source
DGNPPC	Desired GNP per Capita	3-6-14-1	Estimate
DNFG	Desired Nuclear Fraction for Soviet Union	8-1A-2-1	Estimate
EC	Employment Constant	5-3-1	Jobs/$100 million (36)
ELP	Ethnic Lobby Pressure	3-7-2	Estimate
FC	Force Cost	2-10-4	85% of FP (estimate)
FP	Force Price	2-14-1	(1:61)
FPDROW	ROW Force Production Delay	9-4-1	Estimate
FPDUS	U.S. Force Production Delay	7-5-1	Estimate
GNPFSC	GNPF Smoothing Function	5-4-1	Estimate used to predict attainable GNP
GNPGR	GNP Growth Rate	5-2-2	Actual long-term rate (17:109)
GNPSC	U.S. GNP Smoothing Constant	2-12-6	Estimate represents public's economic memory
GNP62	1962 U.S. Real GNP in 1972 Dollars	5-2-1	(32)

Symbol	Name	Eq. No.	Calculation and Source
ROWFL	Row Force Life	10-2-1	Estimate
ROWGNP	ROW GNP	3-6-1	(39:33-71)
ROWHRF	ROW Human Rights Factor	3-6-3	(9); average data and converted to continuous 0-1 scale
ROWIUS	ROW Importance to U.S.	2-1-2-5	(37)
ROWOPD	ROW Order Processing Delay	3-2-1	Estimate
USCL	U.S. Capital Life	7-12-1	Estimate
USCPD	U.S. Capital Production Delay	7-10-1	Estimate
USCPH	U.S. Capital Planning Horizon	7-8-1	Estimate
USFL	U.S. Force Life	1-4-1	Estimate
USFSC	U.S. Force Smoothing Constant	2-12-8	Estimate; represents public's military memory
USHOST	Perceived U.S. Hostility to ROW	6-1-1	Estimate
USIROW	U.S. Importance to ROW	1-6-1	(37)

Symbol	Name	Eq. No.	Calculation and Source
LP	Lobby Price	2-10-3	Estimate
MAXNEI	Maximum Number of Neighboring Countries	3-6-13	Observation
MFRAC	Military Fraction of GNP	8-1-3	(39:33-71)
MGNPF	Militray GNP Factor	3-6-15-1	Estimate
MUSCIP	Maximum Proportion of U.S. Industry Liquidity Available for Capital Production	7-8-2	Estimate
NCI	Number of Countries Including U.S.	0-2	See Appendix B
NCNTRY	Number of Countries	0-1	See Appendix B
NEIGH	Neighbor Array	0-3 to -8	Observation; (37)
OSFRAC	Overseas Deployment Fraction	1-6-2	Estimate
RFNPPC	ROW GNP per Capita	3-6-2	(39:76-114)
RHOST	Perceived ROW Hostility to ROW	1-5-1 to -6	Observation; (37)
ROWCAP	ROW Capital Inventory	8-3-1 to -4	(22:169-178,196-197, 203-222)

Symbol	Name	Eq. No.	Calculation and Source
WI	Industrial Lobby Internal Weighting Factor	2-13-2	Estimate
W2 to W5	U.S. Pressure on Congress International Weighting Factors	2-11-2 to -5	Estimate
W6	PAAT Internal Weighting Factor	3-7-1	Estimate
W7 to W10	USI Internal Weighting Factors	3-6-16 to -19	Estimate
	B. Initial Conditions		
TIME	Time	-------	Set at first year
USCAP(I)	U.S. Capital Inventory	7-11-2	(32:167); 85% capacity assumed
USFC(I)	U.S. Forces in CONUS	1-3-2 to -5	(14; 23; 24; 25)
USFO(I)	U.S. Forces Overseas	1-2-2 to -5	(14; 23; 24; 25)
All Others		-------	Set to zero

APPFNDIX D

EXTERNAL FUNCTIONS

```
      REAL FUNCTION AMAX(WORD,N1,N2,RCNTRY)
      DIMENSION WORD(32)
C
C   FUNCTION AMAX FINDS THE MAXIMUM VALUE OF A VECTOR
C
      NCNTRY=RCNTRY
      X=WORD(1)
      DO 10 I=2,NCNTRY
      X=AMAX1(X,WORD(I))
   10 CONTINUE
      AMAX=X
      RETURN
      END
```

```
      REAL FUNCTION AMAXX(WORDS,N1,N2,RCNTRY,I1)
      DIMENSION WORDS(32,6)
C
C   FUNCTION AMAXX FINDS THE MAXIMUM VALUE OF THE
C               SECOND VECTOR IN THE ARRAY
C
      NCNTRY=RCNTRY
      X=WORDS(I1,1)
      DO 20 J=2,6
      X=AMAX1(X,WORDS(I1,J))
   20 CONTINUE
      AMAXX=X
      RETURN
      END
```

```
      REAL FUNCTION AMAXXX(WORDSS,N1,N2,RCNTRY,I1)
      DIMENSION WORDSS(32,1,6)
C
C   FUNCTION AMAXXX FIND THE MAXIMUM VALUE OF THE THIRD
C                        VECTOR IN THE ARRAY
C
      X=WORDSS(I1,1,1)
      DO 30 J=2,6
      X=AMAX1(X,WORDSS(I1,1,J))
   30 CONTINUE
      AMAXXX=X
      RETURN
      END
```

```
      REAL FUNCTION FIND1(ARRAY1,N1,N2,ARRAY2,N3,N4,J1,J2,J3,RCI)
      DIMENSION ARRAY1(33,4),ARRAY2(33,6)
C
C   FUNCTION FIND1 PERFORMS A MULTIPLE INDEXING OPERATION
C               NOT PERMISSIBLE IN DYNAMO
C
      FIND1=ARRAY1(ARRAY2(J1,J3),J2)
      RETURN
      END
```

```
      REAL FUNCTION FIND2(ARRAY1,N1,N2,ARRAY2,N3,N4,J1,J3,RCI)
      DIMENSION ARRAY1(33),ARRAY2(33,6)
C
C   FUNCTION FIND2 PERFORMS A MULTIPLE INDEXING OPERATION
C              NOT PERMISSIBLE IN DYNAMO
C
      FIND2=ARRAY1(ARRAY2(J1,J3))
      RETURN
      END
```

```
      REAL FUNCTION FIND3(ARRY1,N1,N2,ARRY2,N3,N4,ARRY3,N5,N6,J1,J3,R)
      DIMENSION ARRY1(33,6),ARRY2(33,6),ARRY3(33)
C
C   FUNCTION FIND3 PERFORMS A MULTIPLE INDEXING OPERATION
C                    NOT PERMISSIBLE IN DYNAMO
C
      DO 10 K=1,6
      IF(J1.EQ.ARRY2(ARRY2(J1,J3),K))GO TO 2
   10 CONTINUE
    2 FIND3=ARRY1(ARRY2(J1,J3),K)*ARRY3(ARRY2(J1,J3))
      RETURN
      END
```

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